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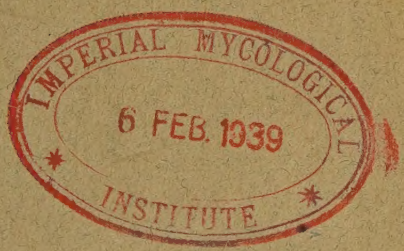

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ACCLIMATIZATION OF SOYBEAN IN THE PHILIPPINES: I

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SIX PLATES

Work on the acclimatization of the soybean, *Glycine max* M., was started by the then Bureau of Agriculture (now Bureau of Plant Industry) in 1911, and as early as 1915 by the College of Agriculture in Los Baños. From 1911 to 1932, about 100 varieties from various countries have been introduced and tested by the former institution. The present work, however, the results of which are being presented in this paper, was begun in May, 1935, and is still in progress.

When the Bureau of Plant Industry first launched its drive on crop diversification in 1931 or thereabout, there was an apparent need for some crops that could be used in our scheme of crop diversification. Because of the great value of soybean in China and Japan as a staple food crop, and its rapidly increasing importance and popularity in the United States and in Europe, together with the fact that the Philippines imports annually over half million-peso worth of this commodity and its products, the soybean was then considered as a potential crop for diversification. The successful production of soybean in the Philippines would not only prove agriculturally beneficial, but it would also bring a decided improvement in the diet of our people, the soybean being considered to be the "most complete and natural food known to the human race" (3).

The soybean is not really a new crop in the Philippines, although it is practically unknown to the farming public. Some even advance the theory that it is indigenous to the Philippines

(3), but the more common belief is that it must have been introduced here during the early Spanish times, perhaps, by Chinese immigrants. This belief is strengthened by the lack of any wild species or form of soybean in the Islands and by the existence of only a single naturalized variety, the Ami, which is claimed to have been grown in the province of Batangas from time immemorial. Although it grows well under local conditions, this variety is small-seeded, late, and irregular in maturity, and not very productive in grains. It is more useful as a forage rather than as a food crop.

The desire to find new varieties adapted to Philippine conditions which would give greater production, mature earlier, and if possible have bigger grains than the Ami was the main objective of this study.

The data presented in this article include results obtained from cultures started in May, 1933 to June, 1937. All the tests were conducted in plot cultures at the Central Experiment Station, Malate, Manila. The field trial tests of the promising varieties in different stations of the Bureau will be reported later in a separate paper.

REVIEW OF PREVIOUS WORK

A number of sporadic attempts to grow soybean in the Philippines was made. In general, these early introductions did not give encouraging results, perhaps, because of the lack of knowledge of the cultural requirements of the plant, or the varieties introduced were not adapted to Philippine conditions. "Variety trials at Singalong and Batangas gave returns of forage and seed that were unsatisfactory. At Alabang and Lamao, the plants grew normally in every way, but were one-third smaller than plants of the same variety in Virginia" (9). Foreign varieties tested by Layosa (7) in the Philippine College of Agriculture did not show promising results.

A rainy and a dry season tests made by the writer in the College of Agriculture, Los Baños in 1924–1925, of several varieties from the Illinois Agricultural Experiment Station, U. S. A., did not also give much promise. Platon,(10) on the other hand, reports that in a year's test of nine newly introduced soybean varieties in the Los Baños College of Agriculture, he found Head Green and American Black promising but not as productive as the Ami.

The progress of the soybean work in the United States was also very slow. Mease (9) wrote as early as 1904 that "the

soybean bears the climate of Pennsylvania very well" and that he recommended its cultivation. Subsequently, although at a much later date, the different state experiment stations of the United States including the United States Department of Agriculture undertook extensive studies of the soybean. Hackleman et al.(4) reported that more than 2,000 varieties and strains were studied and described in the United States, out of which only about 40 were recommended for commercial planting(3). in 1928, it was reported that 45 varieties and over 100 new strains have been tested in the Illinois Agricultural Experiment Station(4). Gray(3) also states that in England over 200 varieties have been tested, out of which only four have been considered to be good for commercial planting there.

While some recommendations were made as early as 1804(9) for the cultivation of soybean in the United States, it was only in 1890 when some farmers undertook its cultivation on a commercial scale(3). The history of the development of the soybean industry in the United States simply emphasizes the difficulties with which a new crop wins its way to recognition. But the soybean success was decisive, as according to Gray(3) "there is no agricultural product that has increased so rapidly in the past decade as the soya plant which has a larger yield of beans than any known legume."

MATERIALS AND METHODS

In this work, advantage was taken of the results of similar work in the United States, Japan, China, Hawaii(1), and India in that only varieties known to be productive have been introduced. Fifty-six varieties have been tested in connection with this study. Table 2 presents the varieties tested, the date of introduction, and the country of origin.

The varieties used in this study were not all tested at the same time because of limited labor, neither were they all tested throughout the duration of the experiment. Five to fifteen varieties were tested in one season. The scheme of the study was by trial and elimination, but a variety was tested at least for two or more seasons before it was eliminated. Out of a number of varieties tested in two seasons, only those found promising by actual performance were planted in the following season together with a batch of newly introduced seeds to replace those that have been discarded. Thus, it will be seen that some varieties were included in practically all the tests while others were tested only in two or more seasons.

TABLE 1.—*Varieties tested and the country of origin.*

Variety name	P. I. number	Date when received	Source
Virginia Early Brown	11439	Mar. 9, 1933	Ohio Experimental Station, U. S. A. [1]
Wilson Early Black	11440	Mar. 9, 1933	Do.
Midwest	11442	Mar. 9, 1933	Do.
Akita	11616	May 16, 1933	Yokohama Nursery, Japan.
Hakubi	11617	May 16, 1333	Do.
Furisode	11618	May 16, 1933	Do.
Otama-ao	11619	May 16, 1933	Do.
Otama-ao Str. 2 [2]	-------	----------	
Otama-ao Str. 3 [2]	13870		
Chinese [3]	-------		Shanghai, China.
Dunfield	12552	May 16, 1934	Illinois Experimental Station, U. S. A.
Illini	12553	May 16, 1934	Do.
Manchu	12554	May 16, 1934	Do.
Mandarin	12555	May 16, 1934	Do.
Macoupin	12556	May 16, 1934	Do.
Cayuga	12798	Feb. 22, 1935	New York Agricultural Experimenta Station, U. S. A.
American Sweet Black	12975	Sept. 25, 1935	College of Agriculture, Los Baños.
Yue Yin Sept. Yellow	12976	Sept. 25, 1935	Do.
Shangtung No. 1	13121	Feb. 26, 1936	Lingnan University, China.
Shangtung No. 2	13122	Feb. 26, 1936	Do.
Lingnan No. 1	13123	Feb. 26, 1936	Do.
Lingnan No. 2	13124	Feb. 26, 1936	Do.
Kuala Lampur No. 1	5309	Oct. 2, 1936	Federated Malay States.
Kuala Lampur No. 2	5310	Oct. 2, 1936	Do.
E. B. 3656	5311	Oct. 2, 1936	Do.
Laredo	5315	Oct. 8, 1936	Hawaii Agricultural Experiment Station.
Nanking	5316	Oct. 8, 1936	Do.
Seaweed	5317	Oct. 8, 1936	Do.
Yellow Biloxi Hybrid	5318	Oct. 8, 1936	Do.
Manchuria [4]	13252	Nov. 6, 1936	Manchuria, China.
Kingwa	13266	Oct. 21, 1936	Virginia Experimental Station, Virginia.
Punjab Chocolate No. 1	13292	Feb. 1, 1937	India.
Punjab Chocolate No. 2	13293	Feb. 1, 1937	Do.
Punjab Yellow Late Italian	13294	Feb. 1, 1937	Do.
Kachin	13716	Mar. 16, 1937	Do.
Penagype	13717	Mar. 16, 1937	Do.
	13770	Apr. 19, 1937	Ceylon.
Mis 1 Pe-Ungype	13782	May 6, 1937	India.
Mis 2 Behrum	13783	May 6, 1937	Do.
Mis 28 E. B. Str. 3910	13784	May 6, 1937	Do.
Mis 33 Didi	13785	May 6, 1937	Do.
Nanksoy	13786	May 13, 1937	China.
Head Green	14229	May 25, 1937	College of Agriculture, U. P.
American Black	14230	May 25, 1937	Do.
Mamlovi	13850	June 5, 1937	Mississippi, U. S. A.
Mamredo	13851	June 5, 1937	Do.
Manchuria 13–177	13852	June 5, 1937	Illinois Agricultural Experiment Station, U. S. A.
Type 117	13853	June 5, 1937	Do.
Type 65379	13854	June 5, 1937	Do.
Mandell	13855	June 5, 1937	Do.
Scioto	13856	June 5, 1937	Do.
Yellow Big	13863	June 18, 1937	India.
Brown	13864	June 18, 1937	Do.
Black	13865	June 18, 1937	Do.
Yellow small	13867	June 18, 1937	India.
Green	13866	June 18, 1937	Do.

[1] Obtained from the cultures of Mr. Manas who was then in charge of soybean and other legume projects.

[2] Selection from Otama-ao.

[3] The seed was confiscated at the Customhouse; shipment came from China, hence the variety name "Chinese."

[4] The seed was imported from Manchuria without name, hence the name "Manchuria."

Tests were made both during the rainy season and the dry season. The idea was primarily to determine the behaviour of the newly introduced varieties when planted at different times of the year and secondarily to enable the multiplication of the promising varieties more rapidly and to insure the supply of viable seeds since soybean is known to lose its vitality in the tropics when kept long in storage(12).

DESCRIPTION OF VARIETIES

No attempt was made to describe the different varieties in detail as was done by Etheridge et al.(2), Morse(8), and Kinney(6). Rather, only the important characters that would easily distinguish a variety from another were taken into consideration. It may be stated here, however, that varietal characters are always more or less variable, being affected by time of planting, seasonal conditions, soil, and other environmental factors. The descriptions here presented were based on characters as they were observed at the Central Experiment Station, Manila.

Wilson Early Black.—Introduced from the Ohio Experiment Station. The plant is slender, medium erect, and has the tendency to twine at the tip; internodes quite long. It grows from about 30 to 70 centimeters. Flower purple; pod gray when matured and fairly well distributed along the vine. The seed is small, oblong, and flattened; seed coat black; hilum black; but cotyledon yellow.

Virginia Early Brown.—Introduced from the Ohio Experiment Station. The plant is slender, and has the tendency to be viny; internodes quite long. Height of plants from about 30 to 50 centimeters. Flower purple; pod tawny when dry, and it is thinly scattered along the stem; seed small, oblong, and flattened; seed coat greenish brown; hilum olive brown; and cotyledon yellow.

Midwest.—Introduced from the Ohio Agricultural Experiment Station. The plant is bushy and erect with medium stem growing to a height of from about 20 to 45 centimeters. (Plate 2, fig. 9). Flower purple; pod tawny when dry; pod formation on central stem terminates abruptly at the tip. Seed medium in size, globose in lateral outline; testa not glossy and buff in color; hilum light to dark brown in color; cotyledon yellow (Plate 6, fig. 20).

Akita.—Of Japanese origin. Plant is bushy and dwarf, growing to a height of from 15 to 25 centimeters. Pod forma-

tion, compact on central stem and ending abruptly at the tip. Pod straw-colored when dry; seed medium small in size; testa glossy and light yellow in color; cotyledon yellow.

Hakubi.—Introduced from Japan. The plant is bushy and erect with practically no branch (Plate 2, fig. 10). Stem coarse and may attain a height of from 20 to 40 centimeters. Internodes are short, and pod formation on central stem, and denser towards the base. Flower purple; pod light brown; seed, medium large, ovoid in shape; testa white; cotyledon yellow (Plate 6, fig. 7).

Furisode—From Japan. The plant is dwarf with few or no branches (Plate 2, fig. 8). The stem is very coarse and attains a height of from 20 to 40 centimeters. Pod formation is bunchy, thicker towards the base, and has a tawny color. Seed large, mostly ovoidal in outline; seed coat greenish brown and not glossy; hilum dark brown; cotyledon greenish yellow (Plate 6, fig. 6).

Otama-ao.—Of Japanese origin. The plant is dwarf and erect, attaining a height of from 15 to 30 centimeters. Hilum coarse; pod formation bunchy (Plate 2, fig. 7). Flower purple; pod brown; seed mostly globose in shape; seed coat dull buff; hilum slate; cotelydon yellow (Plate 6, fig. 26).

Otama-ao Str. 2.—A strain isolated from Otama-ao. The plant is erect, medium-sized, and with coarse stem that has the tendency to branch (Plate 2, fig. 11) ; pubescence tawny; flowers purple; pods dark brown and are more or less clustered along the stem but mostly towards the lower zone of the stem. Seed, of medium size, ovoidal in lateral outline; testa creamy buff in color and glossy; hilum black with yellow median line; cotyledon yellow (Plate 6, fig. 27).

Otama-ao Str. 3.—Also a strain isolated from Otama-ao (see Plate 2, fig. 1). It attains a height of from 30 to 60 centimeters. Flower purple; pubescence tawny; seed, of medium size, ovoidal in lateral outline; testa yellowish green; hilum royal brown; cotyledon light green (Plate 6, fig. 28).

Chinese.—Of Chinese origin. The plant is bushy and erect; stem, of medium size; pubescence tawny; pods light brown when matured and fairly well scattered along the stem (Plate 3, fig. 5). Plant attains a height of from 20 to 50 centimeters. Seed globose in lateral outline, of medium size; testa not glossy and creamy buff; hilum rather small and chamois in color; cotyledon yellow (Plate 6, fig. 4).

Dunfield.—Of Manchurian origin (4) but directly introduced from Illinois Experiment Station. Plant erect; stem medium coarse; pubescence gray; flowers mostly purple; and pods brown. Pod formation is along central stem and prolific (Plate 3, fig. 8). Seed ovoidal to globose in lateral outline; seed coat creamy buff; hilum dark brown; cotyledon yellow (Plate 6, fig. 5).

Illini.—Introduced from Illinois Experiment Station. The plant is erect with few or no branches. Stem rather small; pubescence gray; flower white; pod brown. Its pod formation is on the central stem (Plate 3, fig. 6). Seed medium-sized, globose to ovoidal in lateral view; testa ivory yellow; hilum light brown; cotyledon yellow (Plate 6, fig. 9).

Manchu.—Of Manchurian origin (4) but directly introduced from Illinois Experiment Station. Plant erect and bushy; stem medium-sized but coarse; pubescence tawny; flowers both purple and white; pod dark brown. Pod formation on central stem, prolific (Plate 3, fig. 7). Seed medium large, glossy, mostly ovoidal in shape; testa ivory yellow; hilum dark brown; cotyledon yellow (Plate 6, fig. 13).

Mandarin.—Originally from Manchuria (4) but directly obtained from Illinois Experiment Station. Plant erect and of medium size; stem and leaves, medium-sized; pubescence gray; flower purple; pod forming along central stem and terminating abruptly (Plate 3, fig. 4), gray in color; seed medium large, ovoidal to globes in shape; testa dull buff; hilum dull brown; cotyledon yellow (Plate 6, fig. 16).

Macoupin.—Introduced from the Illinois Experiment Station. Plant erect and bushy, attaining a height of from 30 to 90 centimeters. Stem and leaves medium-sized; pubescence gray; pod formation on central stem, prolific (Plate 3, fig. 9); pod dark gray; seed medium large, oblong to almost spherical, glossy; testa orange yellow; hilum pinkish cinnamon; cotyledon yellow (Plate 6, fig. 12).

Yellow Biloxi Hybrid.—Introduced from the Hawaii Experiment Station. Plant medium large, erect and bushy (30 to 95 centimeters high). Stem big and coarse; flower purple; pubescence tawny; pod formation on central stem, terminating abruptly at tip, and prolific (Plate 2, fig. 2). Pod dark buff, big; seed large, slightly flattened, ellipsoidal to ovoidal in lateral outline; testa cream buff, glossy; hilum dark brown; cotyledon yellow (Plate 6, fig. 34).

Nanking.—Introduced from the Hawaii Experiment Station. Plant erect, dwarfed, bunchy, and compact (Plate 2, fig. 5).

Stem medium coarse; pubescence tawny; flowers purple; pod formation on central stem, dense and compact; pod brown; seed, of medium size, ovoidal to globose in lateral outline; testa light buff and glossy; hilum dark brown; cotyledon yellow (Plate 6, fig. 24).

Nanksoy.—Introduced from Lingnan University, Canton, China. Plant erect, dwarfed. Stem medium coarse; leaves dark green; pubescence tawny; flower purple; pods tawny bunchy and compact (Plate 2, fig. 6). Seed medium, ovoidal to globose in lateral outline; testa creamy buff; hilum light brown; cotyledon yellow (Plate 6, fig. 25).

Seaweed.—Introduced from Hawaii Agricultural Experiment Station. Plant erect, dwarfed, stem medium coarse; pubescence tawny; flowers purple; pods large formed on central stem in a bunchy and compact manner (Plate 2, fig. 4). Seed large, slightly flattened, ellipsoidal in lateral outline; testa greenish buff with black saddle around hilum; hilum light ash; cotyledon yellow (Plate 6, fig. 31).

Kingwa.—Introduced from the Virginia Experiment Station. Plant erect, stem medium in size but stiff; pubescence gray; flower purple; pod light brown and formed rather sparsely along the central stem, terminating abruptly at tip (Plate 2, fig. 3). Seed, of medium size, slightly flattened, ovoidal in lateral outline; testa black; cotyledon black (Plate 6, fig. 11).

Head Green.—An American soybean but directly introduced by the Philippine College of Agriculture. Plant slender, tall, semi-erect tending to twine slightly at tip (Plate 3, fig. 2); pubescence gray; flower purple; pod dark brown and well distributed throughout the stem and branches; seed small, oblong, and slightly flattened; seed coat yellowish green; hilum light brown; cotyledon yellow (Plate 6, fig. 8).

American Black.—Of the United States origin but directly introduced by the Philippine College of Agriculture. Plant tall and rather slender; pubescence tawny; pod dark brown; seed small ovoidal to ellipsoidal in lateral outline; testa black; hilum black with light marking; cotyledon light green (Plate 6, fig. 1).

Kachin.—Introduced from India. The plant is bushy and erect and of the branching type; pod formation bunchy (Plate 4, fig. 3). Stem distinctly coarse; flower purple; pubescence white; pod brown; seed medium small, truncate in lateral outline; testa light yellow; hilum brown; cotyledon yellow (Plate 6, fig. 10).

Penagype.—Introduced from India. The plant is viny and produces many fine branches. Stem fine; flower purple; pubescence gray; pod brown, formed sparsely, and is borne towards the upper half of the vine. Seed very small, subuniform, rather flattened; testa greenish yellow; hilum light brown; cotyledon yellow (Plate 6, fig. 29).

Mis 2 Behrum.—Of Indian origin. Very similar to Kachin in practically all respects (Plate 4, fig. 4) except that the grains are slightly smaller and the pubescence is gray (Plate 6, fig. 21).

Mis. 28 F. B. Str. 3910.—Introduced from India. Plant tall; stem and leaves large and rather coarse; flower white; pubescence gray; pod light brown and clustered along main stem; and branches terminating abruptly at tip (Plate 3, fig. 1). Seed medium small, globular to ovoidal in shape; testa creamy buff, glossy; hilum light brown; cotyledon yellow (Plate 6, fig. 22).

Mis 33 Dixi.—Of Indian origin. Plant tall and is very similar to Mis 28 E. B. Str. 3910 in practically all respects (Plate 3, fig. 3 and Plate 6, fig. 23).

Mamloxi.—Introduced from Mississippi, U. S. A. Plant erect; stem, of medium size but stiff; pubescence gray; flower purple; pod light buff, formed rather compactly along central stem, terminating abruptly at tip. Seed medium large, globose to ovoidal in lateral outline; testa glossy and creamy buff; hilum faint light brown; cotyledon yellow (Plate 6, fig. 18).

Mamredo.—Introduced from Mississippi. Plant erect; stem, of medium size and rather coarse; pubescence tawny; flower white; pod deep buff, formed along central stem, terminating abruptly at tip. Seed, of medium size, globose; testa light buff; hilum prominent and brown; cotyledon yellow (Plate 6, fig. 19).

Scioto.—Introduced from the Illinois Experiment Station. Plant erect; stem, of medium size but rather coarse; pubescence white; flower white; pod dark brown, formed rather compactly along central stem, terminating abruptly at tip. Seed, of medium size, ovoidal to ellipsoidal in shape; testa greenish buff, glossy; hilum prominent and dark brown; cotyledon yellow (Plate 6, fig. 30).

Mandell.—From the Illinois Experiment Station. Plant erect; stem, of medium size; pubescene gray; flower purple; pod straw-colored and borne on central stem, terminating abruptly at tip. Seed large, ovoidal in shape; testa greenish buff; hilum rather prominent and dark brown; cotyledon yellow (Plate 6, fig. 17).

Type 65379.—From the Illinois Experiment Station. Plant erect, stem, of medium size; pubescence gray; flower purple; pod dark brown, borne on central stem, terminating abruptly at tip. Seed, of medium size, globose to ovoidal in lateral outline; testa creamy buff; hilum light brown; cotyledon yellow (Plate 6, fig. 33).

Yellow Big.—Introduced from India. Plant erect; stem coarse; pubescence white; flower purple. Pod brown, rather compact on central stem. Seed medium small; ellipsoidal to truncate in form; hilum prominent, brown; cotyledon yellow.

CULTURES

A total of 14 sets of planting was made in connection with this study, extending for a period of four years, from June, 1933 to the early part of 1937. Seven rainy season cultures were made against seven during the dry season. Two of the dry-season cultures were considered a failure because of the low percentage stand of the crop caused by excessive rain just after planting. Data here presented, therefore, were obtained from only 10 of the cultures, five representing rainy-season cultures, and another five dry-season cultures.

All the cultures were made at the Central Experiment Station, Manila, in garden plots. This fact should be borne in mind in connection with the computed yields per hectare as will be presented later in this paper. Table 2 presents the different sets of cultures, giving the date of planting and of harvesting or maturity.

TABLE 2.—*Dates of planting and harvesting of the different cultures.*

Culture number	Date planted	Date harvested	Remarks
A	June 21, 1933	August 25–September 24, 1933	Rainy-season culture.
B	Oct. 16, 1933	December 22–January 8, 1934	Dry-season culture.
C	Feb. 18, 1934	April 26–May 6, 1934	Do.
D	July 8, 1934	September 21–October 10, 1934	Rainy-season culture.
E	Oct. 13, 1934	January 2–14, 1935	Dry-season culture.
F	Feb. 21, 1935	May 23, 1935	Do.
G	Apr. 3, 1935	July 2, 1935	Rainy-season culture.
H	June 2, 1935	August 22, 1935	Do.
I	Oct., 1935		Dry-season culture.
J	Mar. 18, 1936	June 25, 1936	Do.
K	June 5, 1936	September, 1936	Rainy-season culture.
L	Oct. 10, 1936		Dry-season culture.
M	June 2–6, 1937	August 19–October 23, 1937	Rainy-season culture.
N	July 6, 1937	September 19–November 29, 1937	Do.

Culture A was started with seven varieties; namely, Akita, Furisode, Habuki, Midwest, Otama-ao, Wilson Early Black, and Virginia. At harvest time, two distinct types—dwarf and tall plants—were found in the plots planted to Otama-ao. Because the dwarf plants were predominant they were considered as representing the genuine Otama-ao. The tall plants were called Otama-ao Str. 2. In Str. 2, a few plants with yellow seeds were found; these were again isolated and were labelled in the following culture as Otama-ao Str. 3.

The same varieties in Culture A were the subject of study in Culture B, but instead of having only seven varieties, nine were tested because of the two strains isolated from Otama-ao. In Culture C, again the same varieties in the previous cultures were used with one new addition—Chinese. In Culture D, 11 varieties were tested, namely, Chinese, Dunfield, Furisode, Hakubi, Illini, Macoupin, Manchu, Mandarin, Midwest, Otama-ao Str. 2) and Otama-ao Str. 3. The same varieties were tested in Culture E; Otamao-ao, however, was also included. In Culture F, two new varieties—Cayuga and Manchuria—were added, bringing the total number of varieties tested in this culture to 14.

In Cultures G and H only the three most promising varieties—Dunfield, Macoupin, and Manchu—were tested. The main idea was to test these varieties on a bigger scale and at the same time to produce more seeds for trial planting in some of the experiment stations in the provinces. Culture I was represented by 17 varieties, but the percentage of germination was very low because of excessive rain which followed the planting. In Culture J, seven varieties were tested while in Culture K, only six were included. In Culture L, a number of new varieties including Nanking, Seaweed, Yellow Biloxi Hybrid, and others were tested with the old promising varieties. Culture M was represented by 21 varieties with 12 newly introduced varieties mostly from India, while in Culture N, 12 newly introduced varieties were tested using Macoupin as the basis for comparison.

In Cultures A, B, C, D, E, and F, the planting was done by means of bed system, that is, plots one meter wide and 10 to 20 meters long were prepared for planting, putting two rows in each plot spaced at 50 centimeters far apart. In the rest of the cultures, the seeds were planted in rows set at 80 centimeters far

apart, each variety occupying a row and replicated four or more times. The hills in all cases were planted at 25 centimeters in the rows, allowing two plants to grow in a hill.

In this study, the results may be grouped into two—field observations and experimental data. The field observations were made from planting to maturity, noting down the general behaviour of the different varieties thus enabling the writer to make the general descriptions of said varieties. The experimental data which constitute the main bulk of the results were gathered after the plants were harvested. In the gathering of experimental data the weight of the grains per plant or row was considered as the main criterion for comparison. In some cases the air-dry-weight of the vines and also their heights at maturity were taken.

In the whole acclimatization test, no inoculation was made. However, the different soybean varieties were examined from time to time for their nodule formation, although no critical study on this subject was ever attempted in the present paper. As much as possible, the different cultures, especially the varieties in the same culture, were given practically the same cultural treatments particularly with respect to preparation of the land, cultivation, and weeding.

Owing to the great bulk of the data gathered in this study, it was deemed necessary to present only the summary result of each culture.

EXPERIMENTS AND RESULTS

Culture A.—This was a rainy-season culture; it was conducted from June to September of the year 1933. In spite of the fact that the plots were partially under water during the development of the plants the stand of the crop in general was good. The average height of the different varieties varied from 21.13 $\pm$ 0.17 to 61.96 $\pm$ 0.91 centimeters. The plants showed rather high resistance to standing water—much more than other field legumes like cowpea and mongo. The maturity of the latest maturing variety was overtaken by a 48-hour of more or less continuous rain spell. This caused the decay of the maturing grains. Table 3 gives a summary of the results of this culture.

TABLE 3.—*Average height, weight of straw, and yield of grains of different varieties of soybean, June to September, 1933 planting.*

Variety name	Average height of plant	Average weight of straw per plant	Average weight of beans per plant
	cm.	*gm.*	*gm.*
Akita	21.13±0.17	4.36±0.15	1.14±0.09
Furisode	36.32±0.26	9.22±0.23	8.31±0.13
Hakubi	38.29±0.47	10.87±0.32	9.77±0.24
Midwest	43.06±0.53	13.03±0.37	10.43±0.23
Otama-ao	27.49±0.17	6.91±0.19	7.32±0.17
Otama-ao Str. 2	50.35±0.69	11.50±0.05	7.32±0.14
Wilson Early Black	61.96±0.91	13.36±0.48	8.32±0.19
Virginia [1]			

[1] The maturity of this variety coincided with continuous rain, thus causing the crop to rot.

Culture B.—This culture was undertaken during the early dry season of 1933, from October to December. Nine varieties were tested. While the plants were smaller in size than those in Culture A, the quality of the grains produced was far superior. The average height of the plants varied from 23.02 ± 0.27 to 44.50 ± 0.32 centimeters. Table 4 presents the summary results of this study.

TABLE 4.—*Mean height, weight of straw, and yield of grains of different varieties of soybean, October to December, 1933 planting.*

Variety name	Average weight of plant	Average weight of straw per plant	Average weight of beans per plant
	cm.	*gm.*	*gm.*
Akita	23.02±0.27	5.41±0.19	5.01±0.11
Furisode	26.56±0.32	5.53±0.25	3.93±0.19
Hakubi	32.80±0.41	9.25±0.27	9.04±0.28
Midwest	30.70±0.49	7.75±0.35	6.66±0.28
Otama-ao	25.30±0.04	5.80±0.14	6.31±0.15
Otama-ao Str. 2	36.52±0.46	8.50±0.26	7.75±0.20
Otama-ao Str. 3	39.99±0.51	8.80±0.32	8.29±0.25
Virginia	44.50±0.32	8.98±0.25	6.50±0.15
Wilson Early Black	39.31±0.64	7.06±0.28	6.35±0.21

Culture C.—This culture was a late dry-season crop. It was planted in February and harvested in April to the early part of May, 1934. The plants looked more dwarfish than the previous two cultures of the same variety; the average height of plants here ranged from 18.16 ± 0.27 to 32.32 ± 0.55 centimeters. Being a dry-season crop, however, the quality of the grains was very good. Table 5 gives a summary of the results of this study.

TABLE 5.—*Mean height, weight of straw, and yield of grains per plant of different varieties of soybean, February, April, and May, 1934 crop.*

Variety name	Average height of plant	Average weight of straw per plant	Average weight of beans per plant
	cm.	*gm.*	*gm.*
Akita	18.16±0.27	4.90±0.14	4.88±0.13
Chinese	23.71±0.45	4.33±0.20	4.60±0.19
Furisode	20.23±0.39	5.23±0.20	6.21±0.21
Hakubi	22.78±0.28	6.16±0.20	7.67±0.19
Midwest	22.21±0.32	6.46±0.18	7.22±0.17
Otama-ao	16.72±0.16	4.06±0.11	4.36±0.10
Otama-ao Str. 2	29.17±0.45	8.23±0.27	8.43±0.25
Virginia	32.32±0.55	7.42±0.25	5.16±0.11
Wilson Early Black	29.71±0.60	6.64±0.26	5.73±0.16

Culture D.—Another rainy-season culture. It was planted in July, 1934 and harvested in the latter part of September to the early part of October of the same year. Again, the different varieties showed that they grew taller than those planted from October to January, the average height varying from 28.60 ± 0.51 to 72.73 ± 0.51 centimeters. In this culture the varieties with poor performance in the previous tests were eliminated, and new ones were included. The summary of the results of this test is presented in Table 6.

TABLE 6.—*Mean height, weight of straw, and grain yield per plant of different varieties, July to September and October, 1934 planting.*

Variety name	Average height of plant	Average weight of straw per plant	Average weight of beans per plant
	cm.	*gm.*	*gm.*
Chinese	44.10±0.43	8.26±0.19	4.94±0.12
Dunfield	48.43+0.46	8.56±0.22	7.97±0.22
Furisode	28.60±0.51	9.73±0.58	3.92±0.35
Hakubi	38.20±0.59	10.15±0.48	7.02±0.37
Illini	56.01±0.29	6.49±0.12	7.17±1.10
Macoupin	72.73±0.51	13.09±0.20	12.25±0.23
Manchu	49.30±0.52	6.07±0.14	6.05±0.14
Mandarin	51.94±0.49	7.54±0.18	6.01±0.17
Midwest	40.36±0.63	12.16±0.40	7.30±0.39
Otama-ao Str. 2	42.10±0.59	7.87±0.30	4.35±0.16
Otama-ao Str. 3	46.09±0.61	9.79±0.32	6.63±0.22

Culture E.—A dry-season planting. The first one was planted under a semi-field condition in October, 1934 and harvested in early January, 1935. Being a dry-season crop, the grains were very good and attractive. Four varieties in this test showed great promise as seen in Table 7 wherein the summary of the results of this culture are presented. These varieties were

Manchu, Macoupin, Dunfield, and Illini—all from the Illinois Experiment Station, U. S. A. The plants were also rather dwarf.

TABLE 7.—*Mean yield of straw and grains of 15-meter row spaced at 50 cm. far apart, October, 1934 to January, 1935 crop.*

Variety name	Average yield of straw of 15-meter row	Average yield of grains of 15-meter row	Computed yield per hectare
	gm.	*gm.*	*kg.*
Chinese	385.5±30.93	307.2±27.72	410
Dunfield	460.7±19.46	552.3±16.22	736
Furisode	52.1± 5.77	65.7± 9.81	88
Hakubi	323.5± 6.54	265.1±14.61	353
Illini	416.1±10.37	542.9± 9.99	724
Macoupin	648.8± 6.38	557.4± 9.45	743
Manchu	624.7± 2.32	595.0± 1.99	793
Mandarin	295.2±15.48	347.7± 9.63	483
Midwest	298.1± 9.68	325.8± 9.12	434
Otama-ao	179.6±14.06	185.9±18.95	247
Otama-ao Str. 2	347.3±26.74	320.4±28.33	427
Otama-ao Str. 3	452.1± 8.33	413.5± 8.84	559

Culture F.—This was a late dry-season crop—planted in late February, 1935 and harvested towards the end of May, 1935. The crop was irrigated and also received the beneficial effect of the early rain towards the end of April. The stand of the crop was fair. Although it was overtaken by the first rains in May, the bean crop was still good as the rain then was not yet continuous. Macoupin continued to be the outstanding variety in this culture. Table 8 presents the summary of this culture.

TABLE 8.—*Mean height of plants and grain yield of 10.5-meter row spaced at 50 cm. far apart, February to May, 1935 crop.*

Variety name	Average height per plant	Average yield in beans	Computed yield per hectare
	cm.	*gm.*	*kg.*
Cayuga	31.18±0.45	297.2± 7.74	566
Chinese	39.74±0.60	420.1±26.84	800
Dunfield	35.56±0.75	421.8± 8.86	803
Furisode	22.66±0.45	280.7±14.57	535
Hakubi	27.04±0.49	439.4±12.78	837
Illini	28.24±0.44	401.7± 1.59	765
Macoupin	41.38±0.60	668.0±30.25	1,272
Manchu	29.80±0.56	423.0± 8.86	806
Manchuria	30.76±0.79	280.7±14.56	535
Mandarin	32.14±0.71	239.3± 5.71	456
Midwest	29.86±0.64	318.4± 8.41	606
Otama-ao	19.24±0.35	112.7± 2.48	274
Otama-ao Str. 2	32.08±0.69	461.9± 7.64	880
Otama-ao Str. 3	34.84±0.56	487.1±19.97	928

Culture G.—While this was started late in the dry season (planting in April), it was considered a rainy-season culture because of early heavy rains that year. Three promising varieties were included in this test which was carried in semi-field condition and replicated nine times. The plants were tall and the crop was very good although the harvest was partly spoiled by rain. Table 9 gives the results of this test.

TABLE 9.—*Comparative yields of three promising varieties of soybean, April to July, 1935 crop.*

Row number	Yield per row (20.5 meters long, spaced at 50 cm.)		
	Dunfield	Macoupin	Manchu
	Kg.	*Kg.*	*Kg.*
1	1.010	2.077	0.901
2	1.213	2.165	0.982
3	1.602	2.020	1.269
4	1.367	1.325	1.264
5	1.418	2.116	1.059
6	1.203	2.459	1.609
7	0.956	1.820	1.549
8	1.381	2.305	1.229
9	1.247	2.547	1.454
Mean	1.270 ±0.043	2.092 ±0.076	1.260 ±0.052
S. D.	0.19 ±0.030	0.34 ±0.054	0.23 ±0.036
C. V.	15.07 ±2.47	16.25 ±2.62	18.29 ±2.99
Average yield per hectare in kg.	1,239	2.041	1.229
Average yield per hectare in cavan	21.3	35.0	21.2
Average height of plant in cm.	62.44 ±0.92	86.86 ±0.58	65.38 ±0.77

Culture H.—This was a rainy-season culture of the three varieties tested in Culture G. The culture was conducted from the early part of June to the latter part of August, 1935. In this test, like the former the test, Macoupin was the best yielder. Table 10 presents the results of this study.

Culture I.—This culture was a dry-season planting. It was started in October, 1935, but unfortunately the planting was followed by strong and continuous rains that caused the decay of the seeds resulting in very low percentage of germination. While the growth of the few plants that survived was fair, it was deemed advisable not to include the results in this paper.

Culture J.—This culture was conducted from March to June, 1936. The varieties of less promise were included in this test. Table 11 presents the summary of the results obtained.

Culture K.—This was a rainy-season culture, planted in the early part of June and harvested in the early part of September, 1936. Macoupin was easily the best in performance in this test. Table 12 presents the result of this culture.

TABLE 10.—*Average yield of three promising varieties of soybean, June to August, 1935 crop.*

Row number	Grain yield of 5-meter row spaced 50 cm.		
	Dunfield	Macoupin	Manchu
	kg.	*kg.*	*kg.*
1	0.204	0.300	0.246
2	0.180	0.302	0.224
3	0.156	0.306	0.237
4	0.167	0.306	0.229
5	0.208	0.313	0.239
6		0.290	0.217
7		0.316	0.216
8		0.307	0.261
9		0.300	0.230
10		0.315	0.230
Mean	0.1793 ±0.0029	0.3055 ±0.0016	0.234 ±0.0066
S. D.	0.0105 ±0.0020	0.0076 ±0.0011	0.0293 ±0.0047
C. V.	5.856 ±1.1320	2.4877 ±0.3752	12.505 ±2.0178
Computed yield per hectare	732	1,222 932	

TABLE 11.—*Comparative yield of seven varieties of soybean, March to June, 1936 culture.*

Variety name	Average yield per 5-meter row	Computed yield per hectare
	kg.	*kg.*
Chinese	0.189 ±0.010	756
Furisode	0.174	696
Hakubi	0.263 ±0.014	1,052
Illini	0.191 ±0.005	764
Mandarin [1]	0.186	744
Midwest [1]	0.153	612
Otama-ao Str. 2	0.199 ±0.013	796

[1] Because of limited seed, only one replication was made; the rest were replicated 5 times.

TABLE 12.—*Comparative yield of six varieties of soybean, June to September, 1936 crop.*

Variety name	Average yield of 10.5-meter row	Comparative yield per hectare
	kg.	*kg.*
Chinese	0.455 ±0.010	367
Dunfield [1]	0.313 ±0.052	596
Illini	0.318 ±0.037	606
Macoupin	1.016 ±0.029	1,935
Manchu [1]	0.285 ±0.027	543
Otama-ao Str. 3 [1]	0.257 ±0.033	490

[1] The percentage of germination was rather low which accounted for the low yield.

Culture L.—This was a dry-season culture, the planting having beeng done during the early part of October, 1936. The germination, because of continuous rain soon after planting, was very low. The culture was continued just to save seeds for future plantings, but the data on yield were not determined any more.

Culture M.—A rainy-season culture. Of the 22 varieties planted, five completely failed to germinate; the rest only had a fair germination because of strong rain following planting. There were a few outstanding varieties with respect to growth and pod production e.g., Miss 28, E. B. Str. 3910, Head Green, and Mis 2 Behrum. It was also unfortunate that the date of maturity coincided with rainy days so that no accurate data on grain yield were obtained.

Culture N.—This was a late rainy-season culture, but the newly received seeds had to be planted to save them from losing their viability. Germination was only fair and so with growth. Using the Macoupin variety as the basis for comparison with respect to height of plants and pod bearing quality, Mamloxi and Mamredo were promising. No accurate data from this culture were obtained because of inclement weather towards maturity.

Table 12 was prepared so as to have a comparison of the average height of the plants when planted during the rainy season and during the dry season. Tables 13 and 14, on the other hand, present the comparative average yields of the different varieties when planted during the rainy season and when planted during the dry season.

DISCUSSION OF RESULTS

GENERAL BEHAVIOR OF THE PLANT

Owing to the fact that the soybean is a comparatively new crop in the Philippines, it may be advisable to include here a brief discussion of its local behaviour. Although the soybean is almost exclusively self-pollinated (9) it is rich in strains and varieties (4) which vary greatly in their habit of growth.

Habit of growth.—Of the over 40 varieties studied it was found that they vary in height, growth, and pod-bearing habit, of the plant, in size, shape, and color of seed, and in other char-

TABLE 13.—*Comparative height of soybean when grown at different times of the year.*

Variety name	Average height of plant		
	Early dry season (October to November planting)	Late dry season (February to March planting)	Rainy season (May to June planting)
	cm.	*cm.*	*cm.*
Akita	23.02±0.27	18.16±0.27	21.13±0.17
Cayuga		31.18±0.45	
Chinese		31.73±0.52	44.10±0.43
Dunfield		49.00±0.83	49.69±0.57
Furisode	26.56±0.32	21.45±0.42	31.96±0.39
Hakubi	32.80±0.41	24.91±0.39	38.25±0.53
Illini		28.24±0.44	56.01±0.29
Macoupin		64.12±0.59	70.02±0.54
Manchu		47.59±0.66	53.05±0.62
Manchuria		30.76±0.79	
Mandarin		32.14±0.71	51.94±0.49
Midwest	30.70±0.49	26.04±0.48	41.71±0.58
Otama-ao	25.30±0.04	17.98±0.26	27.49±0.17
Otama-ao Str. 2	36.52±0.46	30.63±0.57	46.23±0.64
Otama-ao Str. 3	39.99±0.51	34.84±0.56	46.09±0.61
Virginia	44.50±0.32	32.32±0.55	
Wilson Early Black	39.31±0.64	29.71±0.60	61.96±0.91

TABLE 14.—*Comparative bean yield per plant of soybean when grown at different times of the year.*

Variety name	Average yield of plant		
	Early dry season (October to November planting)	Late dry season (February to March planting)	Rainy season (May to June planting)
	cm.	*cm.*	*cm.*
Akita	5.01±0.11	4.88±0.13	4.14±0.09
Chinese		4.60±0.19	4.94±0.12
Dunfield			7.97±0.22
Furisode	3.93±0.19	6.21±0.21	6.12±0.13
Hakubi	9.04±0.28	7.67±0.19	8.40±0.24
Illini			7.17±1.10
Macoupin			12.25±0.23
Manchu			6.05±0.14
Mandarin			6.01±0.17
Midwest	6.66±0.28	7.22±0.17	8.87±0.31
Otama-ao	6.34±0.15	4.36±0.10	7.32±0.17
Otama-ao Str. 2	7.75±0.20	8.43±0.25	5.84±0.15
Otama-ao Str. 3	8.29±0.25		6.63±0.22
Virginia	6.50±0.15	5.16±0.11	
Wilson Early Black	6.53±0.21	5.73±0.16	8.23±0.19

TABLE 15.—*Comparative yield of soybean when grown at different times of the year.*

Variety name	Early dry season (October to November planting)	Late dry season (February to March planting)	Rainy season (May to June planting)
	kg.	*kg.*	*kg.*
Cayuga	(1)	566	(1)
Chinese	410	778	367
Dunfield	736	803	[2] 856
Furisode	88	616	(1)
Hakubi	353	945	(1)
Illini	724	765	606
Macoupin	743	1,272	1,733
Manchu	793	806	[2] 901
Manchuria	(1)	535	(1)
Mandarin	463	600	(1)
Midwest	434	609	(1)
Otama-ao	247	274	(1)
Otama-ao Str. 2	427	838	(1)
Otama-ao Str. 3	551	928	[2] 490

[1] Yield was determined by plant.

[2] Percentage of germination was rather low which accounted for the low yield.

TABLE 16.—*Average yield per plant of different varieties of soybean. (Summary of Tables 3 to 6 inclusive).*

Variety name	Average yield of beans per plant	Variety name	Average yield of beans per plant
	gm.		*gm.*
Akita	4.68±0.11	Mandarin	6.01±0.17
Chinese	4.94±0.12	Midwest	7.90±0.27
Dunfield	7.97±0.22	Otama-ao	6.01±0.14
Furisode	5.59±0.22	Otama-ao Str. 2	6.96±0.19
Hakubi	8.37±0.27	Otama-ao Str. 3	7.46±0.23
Illini	7.17±1.10	Virginia	5.83±0.13
Macoupin	12.25±0.23	Wilson Early Black	6.86±0.19
Manchu	6.05±0.14		

TABLE 17.—*Average yield of different varieties of soybean. (Summary of Tables 7 to 12 inclusive).*

Variety name	Average yield of beans per hectare		Variety name	Average yield of beans per hectare	
	Kilogram	Cavan [1]		Kilogram	Cavan [1]
Cayuga	566	9.9	Manchu	861	15.1
Chinese	583	10.2	Manchuria	535	9.4
Dunfield	821	14.4	Mandarin	555	9.7
Furisode	440	7.7	Midwest	551	9.7
Hakubi	747	13.1	Otama-ao	259	4.5
Illini	715	12.5	Otama-ao Str. 2	701	12.3
Macoupin	1,443	25.3	Otama-ao Str. 3	656	11.5

[1] One cavan of soybean weighs, in the average, 57 kilograms.

acters. The characters of the same variety vary according to the season of the year when planted, the condition of the soil, the source of seed, etc. Most of the varieties studied are erect with a well-defined main stem, with or without branches. In some varieties, the stems are elongated, more or less twining, and are suberect or even procumbent. In the bushy varieties, the internodes are generally short and the pods are more or less densely crowded; while in the tall varieties, the internodes are elongated and the pods are scattered (Plate 5). As a rule, plants grown during the rainy season attain very much greater height, and often produce more branches than those grown during the dry season (Plate 4, figs. 1 and 2).

Foliage.—The leaves are trifoliate and they vary greatly in shape, color, size, and in persistence. In practically all the varieties studied, the leaves begin to turn yellow as the pods reach the dough stage. At maturity the plant is practically naked.

Pubescence.—The soybean is hairy, and there is practically little variation in the extent of hairiness. The pubescence is either white (gray) or tawny.

Flowers.—The flowers which are tiny are borne in clusters on short axillary or terminal racemes. The color of the flower is either white or purple. It is during the flowering stage that the plant has the most rapid growth and development which may explain the uniform maturity of the pods of most varieties. Flowers begin to appear in from 20 to 70 days after planting.

Pods.—In most of the varieties studied, the pods are distinctly compressed, although there were a few cases where the pods were rather cylindrical. The size of the pods varies greatly. In most varieties, the number of seeds to the pod is 2 to 3, although occasionally 4 may be found. The pods are borne in clusters, and they may appear crowded or scattered depending upon the length of the internodes. The pods may be gray, straw-colored, tawny, or dark brown at maturity. Some varieties scatter their seeds easily, others do not.

Seed.—The seed varies greatly in size, shape, and color (Plate 6). The most common color is that of straw of varying shades. Black, chocolate, and green colors are also found. The average weight of one cavan of soybean seed is 57 kilograms.

The seed is rich in oil and protein; the protein content is about 36 per cent while the oil content is about 18 per cent (Table 18). This high oil content makes the seed very sensitive to too much moisture in the soil. When sowing is followed by a heavy

rain, the germination is poor and most of the seeds rot. In order to have a good germination, the soil should have an optimum moisture content, and the sowing should be done when there is no danger of heavy rain.

TABLE 18.—*Analysis of some locally grown soybean.*[1]

Variety name	Moisture	Ash	Ether extract	Protein	Crude fiber
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Cayuga	11.40	6.37	16.66	35.94	7.16
Chinese	13.27	6.32	16.65	34.19	8.74
Danfield	14.36	5.72	22.28	32 25	6.06
Illini	11.85	5.92	18.29	36.19	6.10
Macoupin	13.45	5.85	20.86	33.00	7.01
Manchu	14.44	5.86	18.03	37.50	5.88
Manchuria	12.22	6.39	19.42	35.19	6.25
Mandarin	12.47	6.24	17.00	37.00	6.20
Otama-ao Str. 2	12.03	6.22	16.17	37.38	7.05
Otama-ao Str. 3	13.34	6.04	16.47	39.09	6.20

[1] Analysis made by Chemistry Section, Bureau of Plant Industry.

Period of maturity.—The period of maturity varies with the variety and the season of the year when planted. The varieties tested vary in their maturity from 70 to 180 days after sowing. As a rule a variety requires longer time to mature when planted at the beginning of the rainy season. In general, earliness is correlated with the height of the plant, the tall varieties being late maturing.

In this connection, it may be mentioned that a prolonged rain at maturity is detrimental to the beans. They decay very easily when wet over a day at maturity.

THE FIRST INTRODUCTION

The first set of introduction, consisting of seven varieties, represented the materials tested in Cultures A, B, and C, which were made during the different seasons of the year. In Culture A, as seen in Table 3, the four best varieties in bean yield were Midwest, Hakubi, Wilson Early Black, and Furisode. The corresponding bean yields of these varieties were 10.43 ± 0.23, 9.77 ± 0.24, 8.32 ± 0.19, and 8.31 ± 0.13 grams per plant. In Culture B, the four best varieties with respect to bean yield were Hakubi, Otama-ao Str. 3, Otama-ao Str. 2, and Midwest. Their corresponding yields of beans were 9.04 ± 0.28, 8.29 ± 0.25, 7.75 ± 0.20, and 6.66 ± 0.28 grams per plant (Table 4). In Culture C, those found best in the first two cultures were

again the best, namely, Otama-ao Str. 2, Habuki, Midwest, and Furisode. Their yields in beans were 8.43 ± 0.25, 7.67 ± 0.19, 7.22 ± 0.17, and 6.21 ± 0.21 grams per plant respectively (Table 5). It is noteworthy to mention that among the first batch of introduction, Hakubi, Otama-ao Str. 2, Otama-ao Str. 3, and Midwest were the best in performance in the first three cultures made.

SECOND SET OF INTRODUCTION

The second set of introduction included six varieties and these were tested with the promising varieties found in the first set of introduction. In Culture D, the tests were made on a small scale and the determination of yield was done by plant as in Cultures A, B, and C. The stand of the new immigrants was very good (Plate I, fig. 1) and the heights of the new varieties varied from 44.10 ± 0.43 to 72.73 ± 0.51 centimeters. As seen in Table 6, the five best yielders were Macoupin, Dunfield, Midwest, Illini, and Hakubi. Midwest and Hakubi were among the four best in the first set of introduction. The average grain yields of these varieties were 12.25 ± 0.23, 7.97 ± 0.22, 7.30 ± 0.39, 7.17 ± 1.10, and 7.02 ± 0.37 grams per plant, respectively. Variety Macoupin was easily the outstanding leader in yield; it was also the tallest, having an average height of 72.73 ± 0.51 centimeters (Table 6).

In several tests (Cultures E, F, J, and K) where the area devoted to each variety was much greater than in the previous cultures, thus enabling the computation of the yield per hectare, the best varieties based on their ability to produce beans were Macoupin, Hakubi, Illini, Manchu, Dunfield, Otama-ao Str. 2, and Otama-ao Str. 3. The average computed bean yields were 1,317, 747, 715, 714, 712, and 658 kilograms per hectare respectively. Macoupin was easily the best with an average yield of 1,317 kilograms, or 23.1 cavans, per hectare.

In a two-year test of Macoupin, Manchu, and Dunfield (Tables 9 and 10) it was further shown that Macoupin was really superior in yield at the Central Experiment Station. The range in yield of this variety was from 1,222 kilograms (21.4 cavans) to 2,041 kilograms (35.0 cavans) per hectare. Manchu which was second in yield had an average yield of 1,080 kilograms (18.9 cavans) per hectare while Dunfield had an average yield of 985 kilograms, or 17.3 cavans, per hectare. In Southern Illinois where it is generally warmer than in the Central or Northern part of the state, Macoupin and Illini were among the best

five varieties; Macoupin gave an average yield of 26 bushels (29.9 cavans per ha.) while Illini had an average yield of 24 bushels (27.7 cavans per ha.) per acre(5).

In the culture where Macoupin gave an average yield of 35 cavans per hectare the average height of the plants was 86.86 ± 0.58 centimeters, while Manchu and Dunfield in the same culture gave an average height of 65.38 ± 0.77 and 62.44 ± 0.92 centimeters, respectively (Table 9). It seems apparent that the yield in grain is associated with the height of the plant. However, it may be stated in this connection that the height of the plant is a variable character of the soybean plant that is greatly affected by the climatic conditions prevailing during the growing season, as will be shown later.

HEIGHT OF PLANTS

While there has not been any critical study on the effect of climate on the height of the plants, the data on the average heights of plants when planted at different seasons of the year tend to show that the soybeans planted at the beginning of the rainy season were taller than those planted at the beginning of the dry season (October to November plantings). Those planted late in the dry season (February to March plantings) were still more dwarf than those planted at the beginning of the dry season. As typical example, Otama-ao Str. 2 had an average height of 36.52 ± 0.46 centimeters when planted in early dry season, 30.63 ± 0.57 centimeters when planted in late dry season, and 46.23 ± 0.17 centimeters when planted at the beginning of the rainy season (Table 13). The only variety which grew taller during the early dry season was Akita. This variety gave an average height during the early dry season planting of 23.02 ± 0.27 centimeters, 18.16 ± 0.27 centimeters during the late dry-season planting, and 21.13 ± 0.17 centimeters during the early dry-season planting. In this connection it may be remarked that there was no determination of the soil fertility of the different plots used in the cultures. The plots, however, were adjacent to each other and the soil was fairly uniform.

BEAN YIELD AS AFFECTED BY SEASON

In the same way as in the height of the plants, there was no critical study made on the effect of climate on the bean yield of the different varieties. The general trend of the yield was not as marked as the tendency of the height of the plants.

But even at that, it was evident that in the majority of the varieties tested the early rainy season and the late dry season plantings had the tendency to give greater yields than the early dry-season plantings. Macoupin is a typical example of this; its average yield during the early dry-season culture was 743 kilograms per hectare, 1,733 kilograms per hectare for the early rainy season, and 1,272 kilograms per hectare for the late dry season (Table 15). This behavior of the soybean plant makes the problem rather difficult for the reason that the plant grows better and produces a greater crop when the hazards of rain are great, and produces less crop when the conditions favorable for the production of beans of good quality are prevalent. Both the early rainy-season and late dry-season crops are subject to the mercy of rain and typhoon at maturity, so that the yield of a big crop of good quality is a matter of luck. On the other hand, the early dry-season crop, which generally gives beans of good quality produces low yield.

It is of interest to note in this connection that the soybean, as grown locally, seems to maintain its habit of development in Manchuria (its native habitat) and in other temperate countries where it is grown during the summer months (June to September). Fragmentary observations so far made seem to point out that long light duration rather than adequate moisture in the soil is the most important factor that affects the development and growth of the plant. A better understanding of the effects of these factors on the growth and development of the soybean plant will greatly help in the more important task of isolating some varieties and strains that are adapted to dry-season culture. For it is now evident that the effort in soybeen research should be directed towards the isolation or discovery of some varieties or strains for dry-season planting. Breeding may contribute greatly towards the solution of this problem.

PROMISING VARIETIES

Taking the average yields of the different varieties as criterion and without due regard to the season of planting, the most promising among the varieties that were tested for a period of two or more years were Macoupin, Dunfield, Midwest, Illini, Hakubi, Manchu, Otama-ao Str. 2, and Otama-ao Str. 3. These varieties have been and are being tested and cultured on a bigger scale at the Lipa Coffee-Citrus Experiment Station, Lipa, Batangas, and the results of these tests will be reported in a

separate paper. Suffice it to state in this connection that most of the above-mentioned varieties, together with a few newer introductions, have shown more encouraging performances.

As seen in Table 16, the average bean yield per plant of the varieties tested varied from 4.62 ± 0.11 to 12.25 ± 0.23 grams. Macoupin, Hakubi, Dunfield, Midwest, Otama-ao Str. 3, Illini, and Otama-ao Str. 2 were the seven best yielders in their descending order. Their corresponding yields were 12.25 ± 0.23, 8.37 ± 0.27, 7.97 ± 0.22, 7.90 ± 0.27, 7.46 ± 0.23, 7.12 ± 1.10, and 6.96 ± 0.19 grams per plant. Variety Macoupin was easily the best in grain yield.

In the plot tests where the yield of grains per hectare was computed, the range in yield was from 259 kilograms (4.5 cavans) to 1,443 kilograms (25.3 cavans) per hectare (Table 17). With the exception of Midwest, the seven best varieties based on the yield per plant were also the best in yield in these tests, variety Manchu taking the place of Midwest. In their descending order the best yielders were Macoupin, Manchu, Dunfield, Hakubi, Illini, Otama-ao Str. 2, and Otama-ao Str. 3 and their respective average yields were 25.3, 15.1, 14.4, 13.1, 12.5, 12.3, and 11.5 cavans per hectare. Again, Macoupin was easily the best in yield of beans (25.3 cavans per ha.). In a two-hectare planting of this variety made at the Davao Penal Colony last February, 1937, an average yield of 15 cavans of clean beans per hectare was obtained. This speaks very highly of the future of this variety.

RECENT INTRODUCTIONS

Because of the continuous rain that prevailed when the May-to-September, 1937 culture was maturing, no accurate data on yield were obtained. However, based on the stand of the different varieties (Plate 1, fig. 2) and on their pod-bearing characteristics, there were a number of new varieties that were considered very promising. Such varieties as Nanking and Yellow Biloxi Hybrid from the Hawaii Agricultural Experiment Station, Mis 2 Behrum, Mis 33 Dixi and Mis 28 E. B. Str. 3910 from India, Head Green from the Los Baños College of Agriculture, U. P., and Mamloxi from Mississippi may be included among the promising varieties. In stand, a number of the above-mentioned varieties, particularly Yellow Biloxi Hybrid, Mis 33 Dixi, Mis 28 E. B. Str. 3910, and Head Green looked superior to Macoupin and Manchu in grain production.

From the results thus presented in this study, one could readily see the potential possibilities of the soybean as a source of

grain food. This becomes more so when one considers the comparative ease and short duration required in the culture of the crop. But the most important thing about this crop is its multiple uses as a source of raw materials for some industrial arts like soap, varnish, paint, plastics, and other manufactures; as a soil renovator; as an animal feed; and as a human food. The soybean is an excellent source of protein; it contains from 32.25 to 39.09 per cent protein (Table 18). One cannot, therefore, escape the conclusion that this particular food crop would be invaluable in the amelioration of the Filipino diet. Soybean has done wonders with the Japanese soldiers; it, too, will have a great potential usefulness in our scheme of national defense.

SUMMARY OF CONCLUSIONS

This paper presents the results of a 4½-year acclimatization test on soybean involving 56 different varieties introduced from a number of experiment stations in the United States, Hawaii, India, Japan, China, Federated Malay States, and Ceylon. Fourteen separate cultures were made; seven, during the rainy season and another seven, during the dry season.

The results thus far obtained were ever encouraging. The average yields varied with the variety, ranging from a few cavans to over 25 cavans per hectare.

Cultures made during the rainy season produced taller and more branchy plants and gave greater yields of beans than the dry-season cultures. The dry-season plantings gave beans of good quality while the rainy-season cultures were subject to the hazards of rain and typhoon at maturity.

Of the varieties tested for a period of two or more years, seven varieties were considered promising for rainy-season culture. These varieties are Macoupin, Manchu, Dunfield, Hakubi, Illini, Otama-ao Str. 2, and Otama-ao Str. 3. Their average yields varied from 11.5 cavans to 25.3 cavans per hectare, with the first three as the best. There was, however, one great hazard in connection with the rainy-season cultures in that the crop was sometimes partially or totally destroyed if the maturity coincided with rainy days.

Cultures thus far made during the dry season did not give very encouraging results. It was evident, nevertheless, that the varieties which gave the heaviest yields in the rainy-season cultures were concurrently the best in the dry-season plantings.

Of the more recent introductions, nine varieties have shown great promise for rainy-season planting. These are Yellow

Biloxi Hybrid, Mis 33 Dixi, Mis 28 E. B. Str. 3910, Head Green, American Black, Nanking, Mis 2 Behrum, Mamloxi, and Kachin. Some of these varieties, particularly Yellow Biloxi Hybrid, Mis 33 Dixi, Mis 28 E. B. Str. 3910, Head Green, and Mamloxi, have even shown greater possibilities than the Macoupin.

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ILLUSTRATIONS

Plate 1

(*a*) First culture (rainy season) of five American varieties. *1*. Mandarin, *2*. Macoupin, *3*. Illini, *4*. Dunfield, and *5*. Manchu.
(*b*) 1937 rainy-season culture of newly introduced varieties from India.
(*c*) A rainy-season culture of three promising varieties. *1*. Manchu, *2*. Macoupin, and *3*. Dunfield.

Plate 2

Different soybean varieties at maturity showing characteristic pod formation. *1*. Otama-ao Str. 3, *2*. Yellow Biloxi Hybrid, *3*. Kingwa, *4*. Seaweed, *5*. Nanking, *6*. Nanksoy, *7*. Otama-ao, *8*. Furisode, *9*. Midwest, *10*. Hakubi, *11*. Otama-ao Str. 2.

Plate 3

Different soybean varieties at maturity showing characteristic pod formation. *1*. Mis 28 E. B. Str. 3910, *2*. Head Green, *3*. Mis 33 Dixi, *4*. Mandarin, *5*. Chinese, *6*. Illini, *7*. Manchu, *8*. Dunfield, *9*. Macoupin.

Plate 4

Soybean varieties showing characteristic pod formation. *1* and *2* show two varieties when planted at different times of the year: *1-a*. Manchu (rainy season). *1-b*. Manchu (dry season). *2-a*. Macoupin (rainy season). *2-b*. Macoupin (dry season). *3*. Kachin. *4*. Mis 2 Behrum, and *5*. Yelow small.

Plate 5

Varieties of soybean showing different mode of growth, branching, and pod formation. *1*. Dwarf compact, *2*. medium compact, *3*. single stem densely podded, *4*. branched stiffly stemmed with compact pod formation, *5*. finely stemmed with compact pod formation, *6*. stiffly stemmed, sparsely podded, *7*. finely stemmed, sparsely podded.

Plate 6

Grains of different varieties of soybean showing their relative size and shape.

1. American Black
2. Ami
3. Cayuga
4. Chinese
5. Dunfield
6. Furisode
7. Hakubi
8. Head Green
9. Illini
10. Kachin
11. Kingwa
12. Macoupin

13. Manchu
14. Manchuria
15. Manchuria Type 13-177
16. Mandarin
17. Mandell
18. Mamloxi
19. Mamredo
20. Midwest
21. Mis 2 Behrum
22. Miss 28 E. B. Str. 3910
23. Miss 33 Dixi
24. Nanking
25. Nanksoy
26. Otama-ao
27. Otama-ao Str. 2
28. Otama-ao Str. 3
29. Penagype
30. Scioto
31. Seaweed
32. Type 117
33. Type 65379
34. Yellow Biloxi Hybrid
35. Yellow Small

a

b

c

PLATE 1.

PLATE 2.

PLATE 3.

PLATE 4.

PLATE 5.

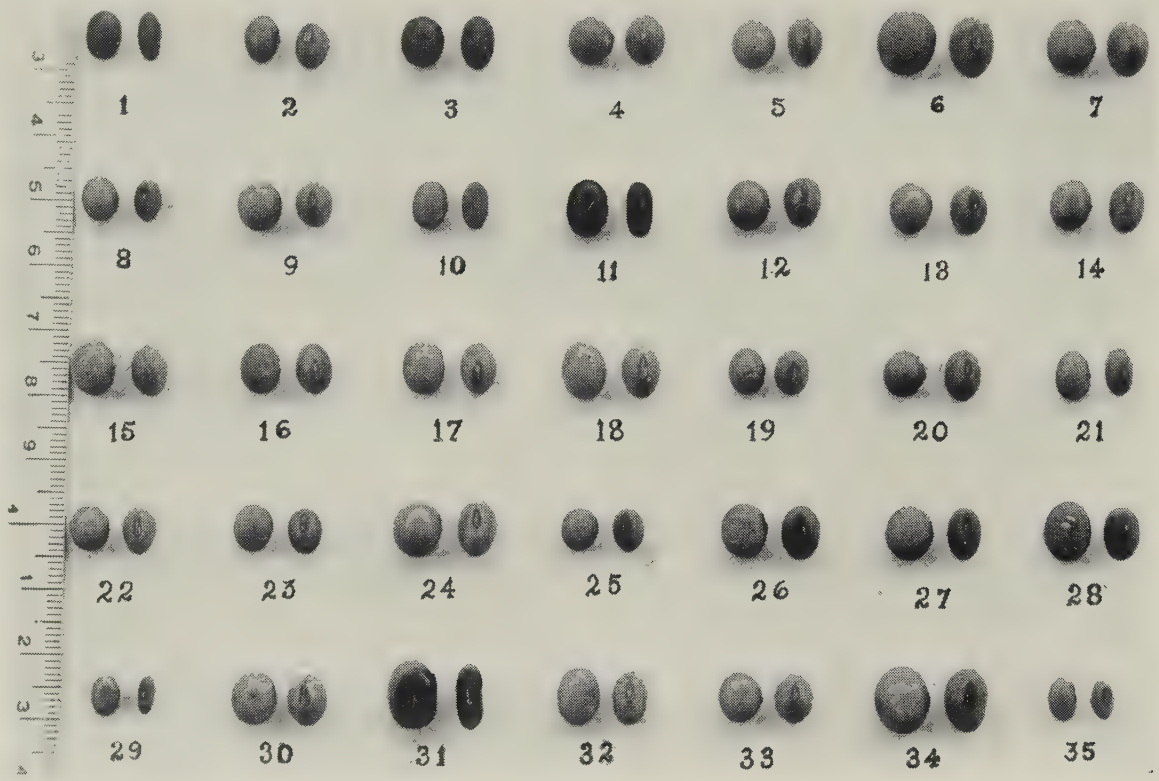
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PLATE 6.

STUDIES ON THE SALT REQUIREMENT OF TOBACCO

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SEVEN PLATES AND ONE TEXT FIGURE

A good understanding of the salt requirement of the tobacco plant helps in effecting a profitable application of fertilizers in tobacco fields which are fast depleting in soil fertility. Also, to be able to recognize the symptoms manifested by the tobacco plant when growing in a medium deficient in any salt or nutrient essential to its normal development, is of considerable practical importance. To attain these objectives, the method of growing plants in "sand and solution culture" was employed in order to make it possible to control the actual supply of nutrients, available to plants, which is virtually impossible to follow in soil-solution films.

REVIEW OF LITERATURE

This paper does not attempt to review the entire literature on the subject but rather to refer only to outstanding contributions dealing directly on the growth behavior of the tobacco plant.

Lieu (2) employed eleven solution mixtures of Type I as outlined by the Division of Biology and Agriculture, National Research Council of the United States [1] and found that no one particular solution could be selected to indicate a fertilizer formula for tobacco, since none of them supported the tobacco to maturity. In his studies he described blackening of petiole of the leaf just emerging from the bud and the subsequent killing of the terminal bud. The solutions used were made up on the basis of a complete nutrient solution prepared from the following salts; namely, KH_2PO_4, $Ca(NO_3)_2$, $MgSO_4$, and trace of iron.

McMurtrey, Jr. (4) succeeded in growing tobacco to maturity in connection with his studies on distinctive effects of the defi-

[1] Livingston, B. E. A plan for coöperative research on the salt requirements of representative agricultural crops. Second edition (1919), Baltimore.

ciency of certain essential elements on the growth of tobacco plants in solution cultures. He employed $Ca(NO_3)_2$, KNO_3, KH_2PO_4, $Mg(NO_3)_2$, NH_4Cl, and iron citrate. In addition to these chemicals added traces of H_3BO_3 and $Mn(C_2H_3O_2)_2$. These two substances were not found in Liu's solution mixture.

MATERIALS, METHODS, AND RESULTS

It is the intention here to discuss only in a broad and general manner the methods of procedure followed in this study. The detailed discussions for "sand and solution culture" work can be obtained by consulting the work of Livingston, Craker, and Kelerman(3).

THE PLANTS

The plants were grown from seeds of tobacco, variety *Ilagan Sumatra* germinated in quartz sand.[1] Sixteen days after sprouting, uniform seedlings were selected and planted in wide-mouthed one-liter bottles filled with complete nutrient solution, or when the bottles were filled with quartz sand, the seedlings were watered daily with complete culture solution mixture. The extra solution in the container was drained off by means of a little opening located at the bottom of the bottle as shown in Figure 1.

Five sets of cultures were made in this study and are designated as *Trial 1*, *Trial 2*, *Trial 3*, *Trial 4*, and *Trial 5*. The plants were grown in the greenhouse of the Tobacco Research Section and each culture was made in duplicate. Before the plants were harvested they were first photographed, after which the roots, stems, and leaves were harvested separately and dried in Freas electric oven to a constant weight. The data obtained from the different trials are recorded in separate tables which will be considered separately.

Trial 1.—The cultures in this trial were made from December 14, 1934 to April 11, 1935. Three types of culture solutions were employed (Table 1) and they differed principally as regards the form of nitrogen present in the culture medium. Type I contained nitrate nitrogen; Type II, the ammonia form; and Type III, both the nitrate and ammonia form of nitrogen. Following Schreiner and Skinner triangular scheme, (5) seven different culture solutions located at strategic points within the triangle were selected for study. These culture solutions varied

[1] Furnished by Ottawa Silica Company, Ottawa, Illinois.

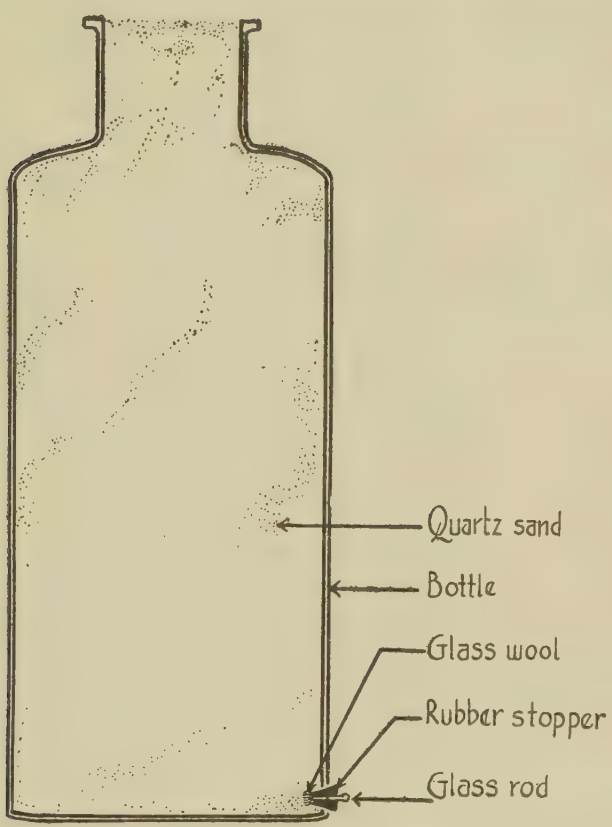

FIG. 1. Longitudinal section of a 1-liter bottle employed in sand-culture work.

in salt proportion, but all had the same total concentration (gram-molecule per liter of all salts). The component parts of the different culture media tried are shown in Table 1.

The plants grown in the three types of culture solutions were photographed twice. The first was taken when the plants were 77 days old since transplanting. Forty-one days later another picture of the same plants was taken before they were harvested (Plate 1-b). The results obtained are shown in Table 2.

The symptoms observed by Liu, such as the blackening of the stem of the leaf just emerging from the bud and the subsequent killing of the terminal bud of the plant were also noted in all the plants grown in the different culture solutions tried in Trial 1. This abnormal growth of the tobacco plants was more apparent in the vigorously growing plants than in the short and stunted ones (Plate 2).

TABLE 1.—*Proportion and concentration of the salts used in Trial 1 in each culture medium. The concentration is in gram-molecule.*

TYPE I

Culture	Salt proportion			
	KH_2PO_4	$Ca(NO_3)_2$	$MgSO_4$	Total concentration
No. 1	.0002	.0010	.0008	.002
No. 2	.0004	.0004	.0012	.002
No. 3	.0004	.0012	.0004	.002
No. 4	.0006	.0008	.0006	.002
No. 5	.0010	.0002	.0008	.002
No. 6	.0010	.0008	.0002	.002
No. 7	.0016	.0002	.0002	.002

TYPE II

Culture	Salt proportion				
	KH_2PO_4	$(NH_4)SO_4$	$Ca(H_2PO_4)_2$	$MgSO_4$	Total concentration
No. 1	.00025	.00075	.00075	.00025	.002
No. 2	.00025	.00075	.00025	.00075	.002
No. 3	.00025	.00025	.00075	.00075	.002
No. 4	.00075	.00075	.00025	.00025	.002
No. 5	.00075	.00025	.00075	.00025	.002
No. 6	.00075	.00025	.00025	.00075	.002

TYPE III

Culture	Salt proportion				
	KH_2PO_4	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$MgSO_4$	Total concentration
No. 1	.00025	.00075	.00075	.00025	.002
No. 2	.00025	.00075	.00025	.00075	.002
No. 3	.00025	.00025	.00075	.00075	.002
No. 4	.00075	.00075	.00025	.00025	.002
No. 5	.00075	.00025	.00075	.00025	.002
No. 6	.00075	.00025	.00025	.00075	.002
No. 7	.00025	.000375	.000375	.0010	.002

NOTE:—$FePO_4$ was prepared as recommended by Livingston and 2.5 c.c of the suspension was added to every 1,000 c.c. of culture solution mixture.

Trial 2.—Culture solution No. 3 of Type I, *Trial 1* produced the tallest tobacco plant, but upon reaching the age of 97 days the young leaves making up the bud showed abnormal growth which finally developed to cause the death of the terminal bud of the plant.

TABLE 2.—*Data from the cultures in Trial 1 obtained at the time of harvest.*

TYPE I

Culture	Culture bottle	Dry weight				General appearance of plant
		Roots	Stem	Leaves	Whole plant	
		gm.	*gm.*	*gm.*	*gm.*	
No. 1	1-a	1.180	1.480	2.047	4.707	Plant, vigorous. Leaves, green. Terminal bud, abnormal.
	1-b	1.215	1.695	2.085	4.995	
	Average	1.1975	1.5875	2.066	4.851	
No. 2	2-a	0.605	0.665	0.960	2.230	Do.
	2-b	0.660	0.575	0.940	2.175	
	Average	0.6325	0.620	0.950	2.2025	
No. 3	3-a	1.555	2.395	2.745	6.695	Do.
	3-b	1.120	2.215	2.395	5.730	
	Average	1.3375	2.305	2.570	6.2125	
No. 4	4-a	0.980	1.510	1.650	4.140	Do.
	4-b	0.985	1.290	1.680	3.955	
	Average	0.9825	1.400	1.665	4.0475	
No. 5	5-a	0.240	0.175	0.515	0.930	Growth, stunted. Leaves, pale green.
	5-b	0.285	0.185	0.450	0.920	
	Average	0.2625	0.180	0.4825	0.925	
No. 6	6-a	1.100	1.435	1.945	4.480	Plant, vigorous. Leaves, green. Terminal bud, abnormal.
	6-b	0.940	1.290	1.755	3.985	
	Average	1.020	1.3625	1.850	4.2325	
No. 7	7-a	0.480	0.145	0.470	1.095	Growth, stunted. Leaves pale green.
	7-b	0.395	0.125	0.480	1.900	
	Average	0.4375	0.135	0.475	1.0425	

Recent literature on the subject points to the importance of boron present in the nutrient medium. This element was not added in the culture solution mixture employed in *Trial 1*. Employing the sand and solution culture methods of growing tobacco, six culture bottles of 1-liter capacity were prepared. These bottles were filled with culture solution No. 3 of Type I (Table 1) but to two of them, in addition to the solution mixture employed, boric acid (H_3BO_3) at the rate of 0.5 cc p.p.m. was added. The bottles were then provided with cork stoppers. A hole, one centimeter in diameter, was bored to every cork stopper. Through the holes, a tobacco seedling was carefully inserted, and to keep the seedling in position so that the roots were

TABLE 2.—*Data from the cultures in Trial 1 obtained at the time of harvest*—Continued.

TYPE II

Culture	Culture bottle	Dry weight				General appearance of plant
		Roots	Stem	Leaves	Whole plant	
		gm.	*gm.*	*gm.*	*gm.*	
No. 1	1–a	1.165	0.060	0.350	0.575	Plant, poor. Growth, stunted. Leaves, green.
	1–b	0.155	0.045	0.195	0.395	
	Average	0.160	0.0525	0.2725	0.485	
No. 2	2–a	0.040	0.020	0.095	0.155	Do.
	2–b	0.045	0.015	0.085	0.135	
	Average	0.0425	0.0175	0.090	0.145	
No. 3	3–a	0.210	0.114	0.330	0.654	Do.
	3–b	0.195	0.105	0.305	0.605	
	Average	0.2025	0.1095	0.3175	0.6295	
No. 4	4–a	0.030	0.025	0.085	0.140	Do.
	4–b	0.050	0.010	0.150	0.210	
	Average	0.040	0.0175	0.1175	0.175	
No. 5	5–a	0.175	0.070	0.255	0.500	Do.
	5–b	0.155	0.060	0.205	0.420	
	Average	0.165	0.065	0.230	0.460	
No. 6	6–a	0.193	0.085	0.245	0.523	Do.
	6–b	0.165	0.060	0.240	0.465	
	Average	0.179	0.0725	0.2425	0.494	

fully immersed in the solution, non-absorbent cotton was placed around the stem of the seedling. The amount of water lost through transpiration was replaced by adding distilled water. The plants were photographed when they were 103 days old (Plate 3) and described as shown in Table 3.

Seedlings of approximately the same size were planted in another four culture bottles filled with quartz sand. The plants were watered daily with culture solution No. 3 of Type I (Table 1). The extra solution was drained off through a small opening made at the bottom of the culture vessel. When the plants were 75 days old, the young leaves of the four plants making up the bud showed symptoms of abnormal growth as shown by the arrow in Plate 4. At this time 0.5 cc, p.p.m. of boric acid (H_3BO_3) was introduced into two of the culture bottles

TABLE 2.—*Data from the cultures in Trial 1 obtained at the time of harvest*—Continued.

TYPE III

Culture	Culture bottle	Dry weight				General appearance of plant
		Roots	Stem	Leaves	Whole plant	
		gm.	*gm.*	*gm.*	*gm.*	
No. 1	1–a	0.565	0.687	1.015	2.267	Plant, fair. Leaves, green Terminal bud, abnormal.
	1–b	0.557	0.780	1.092	2.429	
	Average	0.561	0.7335	1.0535	2.348	
No. 2	2–a	0.420	0.370	0.505	1.295	Do.
	2–b	0.405	0.385	0.575	1.365	
	Average	0.4125	0.3775	0.540	1.330	
No. 3	3–a	0.735	1.115	1.545	3.395	Growth, vigorous. Leaves green. Terminal bud, abnormal.
	3–b	0.605	0.995	1.420	3.020	
	Average	0.670	1.055	1.4825	3.2075	
No. 4	4–a	0.325	0.195	0.475	0.995	Plant, poor. Leaves, pale green. Growth, stunted.
	4–b	0.330	0.190	0.560	1.080	
	Average	0.3275	0.1925	0.5175	1.0375	
No. 5	5–a	0.525	0.720	1.350	2.595	Plant, fair. Leaves, green. Terminal bud, abnormal.
	5–b	0.505	0.690	1.250	2.445	
	Average	0.515	0.705	1.300	2.520	
No. 6	6–a	0.385	0.313	0.710	1.408	Plant, poor. Leaves, pale yellow. Growth, stunted.
	6–b	0.375	0.260	0.690	1.265	
	Average	0.380	0.2865	0.700	1.3365	
No. 7	7–a	0.585	0.740	1.050	2.375	Plant, fair. Leaves, green. Terminal bud, abnormal.
	7–b	0.610	0.760	1.210	2.580	
	Average	0.5975	0.750	1.130	2.4775	

(back, Plate 4), leaving the other two plants (front, Plate 4) continuously watered with culture solution No. 3 of Type I. After a period of four weeks from the date of the introduction of H_3BO_3 the plants were photographed (Plate 4) and described as presented in Table 4.

Trial 3.—The addition of boric acid to culture solution No. 3 of Type I proved necessary for the growth of the tobacco plants (Tables 3 and 4). What form of nitrogen does the tobacco plant prefer in a complete nutrient medium? This was the subject of study in *Trial 3*. Nine 1-liter culture bottles

TABLE 3.—*Effect upon the external appearance and growth of tobacco plant (water culture) of adding H_3BO_3 to a complete culture nutrient solution.*

Date of observation	Complete nutrient solution with H_3BO_3	Complete nutrient solution without H_3BO_3
January 3, 1936	Plant, vigorous. Leaves, green.	Plant, vigorous. Leaves, green.
February 10, 1936	Plant, normal. Leaves, green.	Plant, normal. Young leaves showed sign of crowding. Color of young leaves, light green.
March 10, 1936	Plant, normal. Leaves, green. Margin of lamina, smooth. Leaf-tips, green.	Plant, green. Bud, distorted. Young leaves, light green with a peculiar cupping downward. Base of petioles, pale yellow.
March 24, 1936	do	Growth, abnormal. Matured leaves, light yellow. Young and medium-aged leaves, light green and thickened. Suckers developed, but all buds, dead.
April 10, 1936	Plant, normal. Leaves, green. Margin of lamina, smooth. Leaf-tips, green. Roots normal, white.	Growth, abnormal. Matured leaves, yellow. Medium-aged leaves, pale yellow. Young leaves, light green but lamina thickened, not smooth. Terminal bud, dead. Buds of suckers, dead. Leaves of suckers, pale yellow and buds distorted.

TABLE 4.—*Effect upon the external appearance and growth of tobacco plant (sand culture) of adding H_3BO_3 to a complete culture nutrient solution.*

Date of observation and treatment	General appearance of plant
January 2, 1936:	
All plants watered with culture solution No. 3, Type 1.	All plants, normal. Growth, vigorous. Leaves, green.
January 2 to February 10, 1936:	
All plants watered with culture solution No. 3, Type I.	All plants appeared normal. Young leaves showed sign of crowding. Color of young leaves, light green.
February 10 to March 2, 1936:	
All plants watered with culture solution No. 3, Type I.	All plants showed abnormal bud growth. Youngest leaf, pale green. Base of petioles of leaves making up bud, pale yellow. Buds, ceased to grow with a somewhat drowned appearance, Plate 4.
March 2–30, 1936:	
(*a*) Two plants watered with culture solution No. 3, Type I.	Terminal buds, dead (Front Plate 4). Leaves, thickened, corrugated, and cupped. Curled downward. Suckers, developed but buds dead.
March 2 -30, 1936:	
(*b*) Two plants watered with culture solution No. 3, Type I plus O .5 cc. p. p. m. of H_3BO_3	Normal leaves developed following leaf with distorted leaf-tip (tip of leaf pointed by arrow, Plate 4). Growth of newly developed leaves, normal. Leaves, smooth and green.

filled with pure sand were prepared. The sand used was first washed with a weak solution of formaldehyde and then washed thoroughly with distilled water. Later the sand was dried in Freas electric oven for 3 days at a constant temperature of 100°C. The culture bottles were numbered consecutively from one to nine. Uniform tobacco seedlings (16 days old) were planted to the first six culture bottles, and the last three bottles were not planted (Control). The culture bottles were watered with culture solution as shown in Table 5 and the mouth of the bottles were plugged with cotton (Plate 5). Extra solution was drained off through a little opening at the bottom of the bottle.

TABLE 5.—*Proportion and concentration of culture solutions used in Trial 3. The concentration is in gram-molecule.*

Culture solution number	Salt proportion					
	KH_2PO_4	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$Ca(H_2PO_4)_2$	$MgSO_4$	Total concentration
1	.0004	.0012		.0002	.0004	.0022
2	.0004	.0012		.0002	.0004	.0022
3	.0004	.0012		.0002	.0004	.0022
4	.0004		.0012	.0002	.0004	.0022
5	.0004		.0012	.0002	.0004	.0022
6	.0004		.0012	.0002	.0004	.0022
7	.0001	.0012		.0002	.0004	.0022
8	.0004	.0012		.0002	.0004	.0022
9	.0004	.0012		.0002	.0004	.0022

NOTE.—2.5 cc of $FePO_4$ was added to every 1,000 cc of culture solution. Boric acid was added to every culture solution at the rate of 0.5 cc, p.p.m.

At weekly intervals, during a period of one month, when the plants were already well developed, qualitative nitrate determination [1] was undertaken. Samples of the solution to be tested were drained through small openings located at the bottom of each of the culture bottles and the liquids obtained were immediately tested for nitrate. The results are presented in Table 6. The plants were photographed upon reaching maturity (Plate 5).

[1] Nitrate determination was conducted by Mr. Severino Etorma of the Chemistry Section of the Bureau of Plant Industry.

TABLE 6.—*Description of plants and results of nitrate determination from drainage obtained from culture bottles watered with culture solution as shown in Table 5.*

Drainage from culture solution number	Nitrate test Absent (—) Present (+)	General appearance of plant
1	—	Plant, green. Growth poor, stunted.
2	—	Do.
3	—	Do.
4	+	Plant, normal. Growth, vigorous. Leaves, green. Flowered.
5	+	Do.
6	+	Plant, normal. Growth, vigorous.
7	—	Control (No plant).
8	—	Do.
9	—	Do.

Trial 4.—Does the presence of $Ca(H_2PO_4)_2$ in a complete culture solution as shown in Table 5 make the growth of the tobacco plant more vigorous than when without it? This inquiry was the subject of study in *Trial 4*. Four culture bottles of 1-liter capacity were filled with pure sand and planted with uniformly selected tobacco seedlings. The plants were watered regularly with culture solutions as shown in Table 7. Before the leaves were harvested the plants were photographed first (Plate 6). The results obtained are presented in Table 8.

TABLE 7.—*Proportion and concentration of the salts used in Trial 4. The concentration is in gram-molecule.*

Culture number	KH_2PO_4	$Ca(NO_3)_2$	$Ca(H_2PO_4)_2$	$MgSO_4$	Total concentration
1	.0004	.0012	.0002	.0004	.0022
2	.00044	.00132		.00044	.0022

$FePO_4$—2.5 cc per liter of solution
H_3BO_3—0.5 cc, p.p.m.

TABLE 8.—*Harvest data obtained from tobacco plants fed with culture solutions as shown in Table 7 (Trial 4). The figures are averages of harvests obtained from 2 plants.*

Criteria considered	Culture No. 1	Culture No. 2
Height of plant, cm.	67.5	63.0
Circumference of stem at 10 cm. from base, cm.	1.2	1.0
Number of dry leaves	10.0	8.0
Number of yellow leaves	1.0	1.0
Number of green leaves	14.0	13.0
Total leaf products of green leaves, sq. cm.	1,729.5	1,468.1
Dry weight of roots, gm.	1.8	1.4
Dry weight of stems, gm.	4.22	3.89
Dry weight of all leaves, gm.	5.01	4.25

Trial 5.—The presence of $Ca(H_2PO_4)_2$ in a complete culture solution having a total concentration of 0.0022 molar (all salts taken together) as shown in Table 7 and watered to tobacco plants grown under controlled condition produced bigger plants. What is the optimum molar concentration of the salt mixtures best for the growth of the tobacco plant? This question was the object of study of *Trial 5.* Twelve culture bottles of 1-liter capacity were prepared as usual. They were filled with quartz sand and planted to tobacco seedlings after sixteen days from sprouting. The plants were watered regularly with culture solutions as shown in Table 9. Every culture solution mixture was run in duplicate and tried twice at different times of the year. When the plans were 105 days old from sowing, they were photographed (Plate 7) and later harvested. The data are presented in Table 10.

TABLE 9.—*Culture solutions employed for Trial 5. The ratio of the molar proportion used in Trial 4 was kept constant, but the total concentration of all the solts taken together was made variable. The concentration is in gram-molecule.*

Total concentration	Molecular proportion			
	KH_2PO_4	$Ca(NO_3)_2$	$Ca(H_2PO_4$	$MgSO_4$
.00055	.0001	.0003	.00005	.0001
.0022	.0004	.0012	.0002	.0004
.0088	.0016	.0048	.0008	.0016
.0132	.0024	.0072	.0012	.0024
.0220	.0040	.0120	.0020	.0040

$FePO_4$—2.5 cc per liter of solution
H_3BO_3—0.5 cc, p.p.m.

DISCUSSION OF RESULTS

The external appearance of the plants was used as the basis of comparison for the relative nutritive value of the different culture media employed in this study. The other criteria, like height, dry weights, and other quantitative characters, are here considered as supplementary only. The reason for this is that two plants may appear alike in dry weights or in heights, but may differ markedly in the presence or absence of some physiological abnormalities, like drying of leaf tips and buds and leaf coloration.

TABLE 10.—*Harvest data obtained from tobacco plants watered with culture solution mixtures as shown in Table 9 (Trial 5). The figures are averages of results obtained from two plants.*

	Total concentration (gram-molecule) of culture solution (Table 9)				
Criteria considered	.00055	.0022	.0088	.0132	.022
Height, cm.	32.2	86.5	92.1	96.2	65.2
Diameter of stem, mm.	4.0	6.0	8.0	8.0	5.5
Number of leaves	8.0	13.0	15.0	15.5	12.5
Leaf products of all leaves, sq. cm.	576.5	2,366.0	2,505.0	2,730.0	1,820.0
Dry weight of stem, gm.	1.41	5.89	6.02	6.81	4.55
Dry weight of roots, gm.	.60	2.52	2.75	3.0	2.0
Dry weight of leaves, gm.	1.72	7.24	7.95	8.38	5.59
Dry weight of whole plants, g.	3.73	15.65	16.72	18.19	12.14
Color of fresh leaves	Pale green	Normal green	Normal green	Normal green	Dark green

GROWTH DEVELOPMENT OF TOBACCO PLANT IN DIFFERENT NUTRIENT MEDIA

The tobacco plants fed with culture solution mixtures of Type I were generally better developed than those grown in Types II and III (Plate 1-a and Table 2), yet not a single plant in Type I grew normally toward the later stage of growth development. When the plants were 90 days old (Plate 1-b), especially those in culture solutions Nos. 1, 2, 3, and 4 of Type I and culture solutions Nos. 1, 3, 5, and 7 of Type III, they had distorted terminal buds. The young leaves making up the bud first showed manifestation of a light green color. Later the base of the petioles changed from pale green to pale yellow. This was followed by the death of the terminal bud. The leaves already produced continued to grow. The lamina thickened and curled downward. Generally the youngest leaf, if it develops at all shows a missing tip and a cut-out outline of the margin. This bud abnormality was not visible in the poor and stunted plants, such as those grown in the different culture mixtures of Type II, but was most apparent in plants grown in culture solution No. 3 of Type I. However, these plants were the biggest and best developed in the whole set (Plate 2).

The death of the terminal buds of the tobacco plants may be attributed to three causes, namely, (1) physical injury such as insect bites, (2) fungus infection, and (3) the nutrient medium in which the plants were grown. The first two possible causes of the death of the buds were eliminated on the basis of the find-

ing of the Chief of the Pathology Section, Bureau of Plant Industry, that no physical injury nor pathogen was observed on dead buds placed in an agar culture medium. It was very probable, therefore, that the death of the buds of the tobacco plants was due to the absence of a certain element or elements in the nutrient medium necessary for continuous normal growth of the tobacco plant. None of the three types of culture solution mixture employed in *Trial 1* was found satisfactory to growing normal tobacco plant to maturity.

The NH_4-free culture, Type I.—At the early stage of growth development the tobacco plants, which were supplied with nitrate-nitrogen, grew vigorously. The leaves were normal and green and the plants were the best developed in the entire set; but at a later stage of growth when the plants were 90 days old, the young leaves making up the bud showed manifestation of yellowing which was finally followed by the death of the terminal bud. This bud malady was most noticeable among the vigorously growing plants. The other plants in the NH_4-free culture (Table 1) also exhibited varying degrees of bud abnormalities (Plate 2). And as usual, the smallest developed plants showed no visible bud abnormality. The culture solution that produced the best developed plant, although exhibiting the most apparent bud abnormality, contained 0.0004 M KH_3PO_4, 0.0012 M Ca $(NO_3)_2.4H_2O$, .0004 M $MgSO_4.7H_2O$, and 2.5 cc of $FePO_4$. At the age of 90 days, the plant fed with this salt mixture had a total average dry weight of 6.21 grams per plant.

The NO_3-free cultures, Type II.—Plants supplied with ammonia-nitrogen showed early manifestation of stunted growth. There was no visible bud abnormality but the growth of the plant was decidedly stunted. This was attributed to the absence of nitrate-nitrogen in the culture medium (Table 1). The average dry weights of plants grown in culture medium supplied with ammonia-nitrogen were all lighter than those which were supplied with nitrate-nitrogen (Table 2, Type II). The biggest plant in the former had an average total dry weight of only 0.62 gram, while in the latter, the best plant had an average dry weight of 6.21 grams per plant.

Cultures containing NO_3-and NH_4-nitrogen, Type III.—The plants fed with culture solution containing both the nitrate- and ammonia-nitrogen were found better developed than those plants fed with ammonia-nitrogen only (Table 1 and Plate 1). But the best developed plants in this group also showed distorted terminal buds similar to those observed in Type I (the NH_4-free

cultures). The bud abnormality was always most apparent in the vigorously growing plants. The best plant in this group produced an average total dry weight per plant of 3.20 grams which was approximately one-half as heavy as the heaviest plant supplied with nitrate-nitrogen only.

Boric acid added to NH_4-free culture solution.—Tobacco plants grew vigorously (Plates 3 and 4) without any symptom of bud abnormality (Plate 3, right plant) in culture solution No. 3, Type I, when boric acid was added to the culture solution. The plants grown in culture solution No. 3, Type I, but without boric acid (first two plants from the left, Plate 3) showed the same bud abnormality as had been described elsewhere in this paper upon reaching the age of 90 days. And at the more advanced stage of abnormal development, when they were 103 days old, the buds of these boronless plants died. Similarly, the plants grown by the sand culture method and fed with the same culture solution (culture solution No. 3 of Type I) from January 2 to March 2 of 1936 also showed symptoms of abnormal growth (pointed by arrows) of the young leaves making up the bud (Table 4 and Plate 4, back plants). On March 2, boron was then introduced into each of the culture medium. Normal leaves were then again developed by the plants (leaves above arrow) as shown in Plate 4 (back plants) after a period of 4 weeks. The other two plants (front), which were continuously fed with culture solution No. 3, Type I, for the same length of time, had dead terminal buds. This behavior of the tobacco plants grown under the conditions herein described (both water and sand culture method) shows that boron, especially for tobacco, is essential and therefore must be present in the nutrient medium. This result further substantiates the recent findings on the nutrition of higher plants that boron is to be included as one of the essential elements for normal growth of these plants. It is one of the rare elements and like the rest of the rare elements, it was heretofore considered not essential to the growth of higher plants.

Preference of NO_3-nitrogen over NH_4-nitrogen.—The tobacco plant showed decided preference to nitrate-nitrogen over ammonia-nitrogen. The results of *Trial 3* (Tables 5 and 6) show that when the source of nitrogen was from $(NH_4)_2SO_4$, the rate of growth of the tobacco plant (Plate 5) was greatly retarded, if not inhibited; whereas when $Ca(NO_3)_2$ was supplied, the plant did not only show vigorous growth but also reached full maturity (Plate 5). It is apparent from this fact that under

field conditions ammonia-nitrogen has to be converted into nitrate-nitrogen by nitrifying bacteria in order to become readily available to the tobacco plant. This contention is supported by the absence of nitrate obtained from the drainage of culture bottles Nos. 1, 2, and 3, Table 5, which were supplied with ammonium salts. Similarly, nitrate-nitrogen was absent in control bottles Nos. 7, 8, and 9, Table 5, which were treated identically as culture bottles Nos. 1, 2, and 3 except that no plants were grown in them. It is obvious, therefore, that the absence of nitrate-nitrogen in the drainage of cultures Nos. 1, 2, and 3 was not due to the immediate absorption of nitrate-nitrogen by the roots as fast as it was converted from ammonia-nitrogen by the nitrifying bacteria but was due to the absence of the necessary nitrifying bacteria in the culture medium to effect the necessary transformation of the ammonium salts into the nitrate form. Tobacco is, therefore, unlike other crop plants like the pineapple which according to Stewart(6) and others, is capable to assimilate all its nitrogen in the form of ammonium salts, although the best growth was made by those growing in solutions in which the nitrogen was present in the form of nitrates. Also the results of numerous investigators on the nitrogen nutrition of many plants indicate that some plants grow equally well with both nitrates and ammonium salts and that others, although assimilating nitrogen in the absence of nitrates, seem to prefer nitrates. It is now clear that the tobacco plant belongs to the latter group. This nutrient requirement of the tobacco plant is, therefore, extremely important to consider in the application of commercial fertilizers in tobacco fields. Ammonium salts may be also applied, but the acidity of the soil must be taken into consideration, because the nitrogen-fixing bacteria are very intolerant to acid. Under such condition it is advisable to apply the nitrate salts in the tobacco field instead of the ammonium salts.

The effect of adding $Ca(H_2PO_4)_2$ *to a complete nutrient medium.*—The addition of a small quantity of $Ca(H_2PO_4)_2$ to a nutrient medium containing KH_2PO_4, $Ca(NO_3)_2$, $MgSO_4$, $FePO_4$ and H_2BO_3 improved the nutritive value of the mixture as shown by better growth developments to tobacco plants grown with it than when without $Ca(H_2PO_4)_2$ (Plate 6 and Table 7). The total concentration (gram-molecule per liter) and molecular proportion of the salts employed in the two culture media were the same. The only noticeable differences of the two culture media used were due to more Ca and PO_4 ions in the nutrient medium containing $Ca(H_2PO_4)_2$. These two ions were, however, also

found in the other culture medium only that they were present in fewer number. This difference brought about in the latter a reduction in growth development of the tobacco plant. The plant grown in culture medium with $Ca(H_2PO_4)_2$ had a total dry weight (roots, stem, and leaves) of 11.03 grams as against 9.54 grams of the other. The leaf products of green leaves of the former averaged 1,729.5 sq. cm; that latter, 1,468.1 sq. cm. There were, however, no noticeable differences observed as regards the quality of the leaves harvested from the two culture media.

Influence of concentration on the growth of tobacco.—The nutrient medium, which was found to grow tobacco to full maturity under controlled condition (sand culture), had about .0022 gram-molecule per liter (all salts taken together), the salts being present in about the following molecular proportions:

KH_2PO_4: $Ca(NO_3)_2$: $Ca(H_2PO_4)_2$: $MgSO_4 = 2:6:1:2$. $FePO_4$ and H_3BO_3 were added to the culture solution in the amount of 2.5 cc per liter for the former and 0.5 cc p.p.m. for the latter (Table 5 and Table 6). Results of *Trial 5* show that when the molecular proportion of the salts employed was kept constant but the total concentration was made variable, the growth development of the plants grown therein varied a great deal. Repeated trials on the determination of the optimum concentration for tobacco show that .0132 molar was better than 0.0022, Table 10.

Height of plants.—The height of the plants was affected by the total concentration of the nutrient medium. A total concentration of the nutrient medium as low as .00055 molar or as high as 0.022 were both not favorable nor conducive to rapid growth of the tobacco plant. The best strength of the solution mixture tried was found to be 0.0132 molar. The plants grown therein had reached an average height of 96.2 cm at the age of 103 days. Plants grown in nutrient media with concentrations lower or higher than .0132 molar were shorter. When the plants were arranged in the order of height beginning from the highest to the lowest, the order of the total concentration of the solution employed was .0132, .0088, .0022, .022, and .00055 molar, respectively. When a value of 100 is given to the highest plant (in the .0132 molar), the relative value of the height of the other plants arranged in the same order from the highest to the lowest would be 100, 96, 90, 68, and 33.

The plants which grew the highest also produced the biggest leaves. When the dry weight of the whole plants was considered (roots, stem, and leaves), the plant grown in the .0132 molar was also the heaviest. It is apparent, therefore, that .0132 molar was the optimum concentration for tobacco. This concentration, .0132 molar, is very much higher than the optimum concentration of the nutrient medium tried for rice. According to Espino(1), the most promising solution for this plant has about 0.002 gram-molecule per liter (of all salts). This strength is approximately six and six-tenths weaker than that one best for tobacco. Judging from the concentration requirement of the two kinds of plants, it can be interpreted that tobacco is a heavier consumer of food elements present in the soil than rice. This is obvious when one observes the relative sizes of fully matured rice and tobacco plants and especially so when the relative sizes of the seed materials are taken into consideration.

SUMMARY AND CONCLUSION

The sand and solution culture methods were employed in the study of the salt requirement of tobacco plant, with special reference to the variety *Ilagan Sumatra*. Sixteen-day-old seedlings (from sowing) germinated in quartz sand were employed. The results of the different trials point to the following:

1. The most promising nutrient medium for tobacco has about 0.0132 gram-molecule per liter (of all salts), the salts being present in about the following molecular proportions: KH_2PO_4: $Ca(NO_3)_2$: $Ca(H_2PO_4)_2$: $MgSO_4 = 2:6:1:2$. As usual, trace of iron in the form of ferric phosphate or ferrous sulphate is added to the culture medium.

2. In addition to the 10 essential elements, namely, carbon, hydrogen, oxygen, phosphorus, potassium, sulphur, nitrogen, calcium, iron, and magnesium needed for normal growth of higher plants, a little amount of boron is absolutely necessary to be present in the nutrient medium in order for the tobacco plant to develop to full maturity. Its absence in the nutrient medium causes the death of the terminal bud of the tobacco plant.

3. The addition of a small quantity of $Ca(H_2PO_4)_2$ to a nutrient medium containing KH_2PO_4, $Ca(NO_3)_2$, $MgSO_4$, $FePO_4$ and H_3BO_3 improves the nutritive value of the mixture.

4. The tobacco plant develops vigorously in a complete nutrient medium containing nitrate-nitrogen. In using ammonium sulphate as source of nitrogen in the absence of nitrifying bacteria, the growth of the plants is greatly retarded, if not inhibited.

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ILLUSTRATIONS

TEXT FIGURE

FIG. 1. Longitudinal section of a 1-liter bottle employed in sand culture work.

PLATE 1

a. Showing the plants as they appeared on March 1, 1935. The salts used in culture media are shown in Table 1.

b. Showing the same plants (1-a) as they appeared on April 11, 1935. The salts used in culture media are shown in Table 1. Plants were harvested on April 11. Numerical data are in Table 2.

PLATE 2

Showing the plants as they appeared on April 11, 1936. The salts used in culture media are shown in Table 1. Note the deformed young leaves (indicated by arrows) of the tall plants.

PLATE 3

Showing the plants as they appeared when they were 103 days old (from sowing). Plant on the right was grown in complete nutrient solution with H_3BO_3. The other two plants were also grown in complete nutrient solution but without H_3BO_3. Note the terminal buds. Description of plants are in Table 3.

PLATE 4

Showing plants (sand culture) as they appeared when they were 103 days old (from sowing). At the start, the four plant were all fed with culture solution No. 3 of Type I. At the age of 75 days, abnormal growth of leaf was noted as shown by arrows. H_3BO_3 was then introduced into the culture media. The other two plants (front) were fed continuously with culture solution No. 3 of Type 1. Note the condition of the terminal buds.

PLATE 5

Showing plants as they appeared when they were 115 days old. The salts used in culture media are shown in Table 5. Plant on the left was supplied with ammonia nitrogen ($-(NH_4)_2SO_4$) and the other, right with nitrate nitrogen ($Ca(NO_3)_2$). Description of plants is presented in Table 6.

PLATE 6

Showing plants as they appeared when they were 103 days old. The salts used in culture media are shown in Table 7. Numerical data are presented in Table 8. Two plants on the right were fed with $Ca(H_2PO_4)_2$ and in the other two plants (left) $Ca(H_2PO_4)_2$ was absent in the culture media.

PLATE 7

a. Showing plants (first trial) as they appeared when they were 95 days old. The salts used in culture media are shown in Table 9 and culture bottles were arranged from lowest (left) to highest (right) concentration.

b. Showing plants (second trial) as they appeared when they were 103 days old. The salts used in culture media are shown in Table 9 and culture bottles were arranged in the same order as of Plate 7-a. Harvest data are presented in Table 10.

a

b

PLATE 1.

PLATE 2.

PLATE 3.

PLATE 4.

PLATE 5.

PLATE 6.

a

b

PLATE 7.

SOME OBSERVATIONS ON THE LIFE HISTORY, HABITS, AND CONTROL OF THE RICE CASEWORM, NYMPHULA DEPUNCTALIS GUEN.

By Pedro Sison

Of the Plant Pest and Disease Control Division

FOUR PLATES AND ONE TEXT FIGURE

The rice caseworm, *Nymphula depunctalis* Guen., is one of the most important rice pests in the Philippines, causing at times serious damage. During the years 1927 and 1929, infestations by this pest were reported alarming in the Ilocos provinces, Pampanga, Tarlac, Bulacan, and Rizal by fieldmen of the old Bureau of Agriculture (now Bureau of Plant Industry) stationed in these provinces. Aniceto G. Toquero, assistant agronomist, reported in 1934 that it was serious in the provinces of Bulacan and Nueva Ecija. In the municipality of San Jose, Nueva Ecija, alone, Toquero observed an area of about fifty hectares so seriously damaged by the pest that the owners decided to replant the entire area in order to obtain a paying crop. Similar cases of this nature have been observed by the writer in other rice-growing regions. In fact the injuries caused by this pest are the subjects of complaints received by the Bureau of Plant Industry from rice growers every year.

This study was, therefore, conducted with the object of obtaining data or information on the life history, habits, and control of this important pest of lowland rice so that growers who are often troubled by this insect may be helped. The observations in this paper may also serve as a basis for further investigation.

CLASSIFICATION AND VERNACULAR NAMES

The insect belongs to the Order Lepidoptera (Heterocera), Family Pyralidæ. The adults reared during this study and those collected from the field agree with the descriptions by Maxwell-Lefroy (6) and Dammerman (1) who identified the insect as *Nymphula depunctalis* Guen. (*stagnalis* Zell). Furthermore,

the adult specimens reared in this work were found identical with those in the collection of the Philippine Bureau of Science, Manila. The Bureau of Science specimens were collected from lighted spots near "zacate" fields within the City of Manila on October 11, 1906, and were identified by Charles S. Banks, former entomologist of the said Bureau, as *Nymphula depunctalis* Guen, basing his identification on Hampson's (1896) description of the species in the later Fauna of British India (Vol. IV., p. 185).

Hampson(5) and Moore(9) listed the following as synonyms of the species:

Nymphula stagnalis Zell. (1852)
Zebronia decussalis Wlk. (1854)
Hydrocampa depunctalis Guen. (1854)

The pest is commonly known as the rice caseworm, because the caterpillars have the habit of enclosing themselves in pieces of rice or grass leaves in the form of cases, or coverings. The leaf cases undoubtedly serve as a protection for the larvæ from natural enemies and also as a float to facilitate movement from one plant to another.

In the Tagalog provinces, rice farmers call the pest "aksip na puté" (white malady), a term applied to the effect of the insect's injury as the infested fields, as a whole, appear white from a distance and are clearly distinguishable from the non-infested portions of the field. In the Ilocos provinces, it is named "cutalo," while in the Province of Pampanga, the pest is known as "dalukat aputi," etc.

GEOGRAPHICAL DISTRIBUTION

In the Philippines, Woodworth(13) and Uichanco(12) listed this insect as one of the pyralid pests of rice. According to Dammerman(1), Miller and Padgen(8), and Corbett(2) this insect is often serious on rice in the Malay Archipelago. In India, Gupta(4) reports its presence on rice in Assam Province and Ramakrishna(11) in South India. Maxwell-Lefroy(7) also states that *Nymphula depunctalis* is widely distributed and is common in India. Ghosh(3) says it is of common occurrence in lower Burma. Wardle(14) referred to this insect as one of the chief pests of rice in Southeastern Asia, which comprises

China, Japan, Formosa, the Philippines, Indo-China, the Malay Peninsula, East Indies, India, and Ceylon. Leefmans(8) also mentioned it on rice in the Dutch East Indies.

This pest is, therefore, widely distributed, being known to occur wherever lowland rice is grown.

NATURE AND EXTENT OF DAMAGE

The larvæ, soon after emerging from the eggs, begin to feed on the lower surfaces of the tender leaves of rice or grasses, leaving the upper epidermis which is papery and which gives the infested plants their characteristic white appearance. Most of the tips of the leaves are cut, because these severed portions are used by the larvæ for their cases, or coverings (Plate 3). When young seedlings are attacked by four or more larvæ per stool, as observed under field conditions, almost all the lower surfaces of the leaves are usually eaten up within a few days and the destroyed portions of the leaves soon dry out. This renders the plants leafless and become greatly stunted. When the rice plants are injured to this extent, it may take them about a month to recover. However, when adverse weather conditions follow and the field is overgrown by weeds, the whole planting may become useless and replanting may be necessary.

Not only are the transplanted seedlings attacked by this pest but also those still in the seed beds, as was observed in Arayat, Pampanga, in 1936. After a serious attack, the seedlings in the seed beds appear as though they were affected by drought, because the infested leaves become dry even if the stems are still fresh.

The larvæ also attack older seedlings, but the rice plants can better resist the injury and recover more readily as the growth is only little retarded. When the pest, however, still appears in paddies where the rice plants approach maturity, the larvæ no longer bother them, because the leaves are already tough and instead, they feed on the leaves of grasses growing among the rice plants.

The infestations occur in patches, ranging from a few paddies of limited area to many solid hectares. Solid infestations in one locality may even reach as much as fifty hectares or more in extreme cases, as was observed by Mr. Toquero in the municipality of San Jose, Nueva Ecija, during the year 1934. The plants that recovered from the attack of the pest are stunted,

and therefore head at a much later time. The panicles produced are smaller than those of the plants not or only slightly affected.

HOST PLANTS

Rice is preferred by the larvæ of this insect, but they also subsist on the leaves of grasses. The insect seems to show no decided preference to any variety of lowland rice, as has been observed in several provinces. In Pampanga, for example, it was observed to feed on the varieties macan, elon-elon, and ramai. In Rizal province, it attacks the macan and malagkit, or glutinous varieties. In the Bicol provinces, it occurs on the varieties baranay and senador, or apostol, etc.

Among the grasses, found in the province of Rizal, on which the pest feeds, as identified by E. Karganilla of the Bureau of Science, are the following:

1. *Panicum carinatum* Presl.
2. *Panicum colonum* Linn.
3. *Eragrostis interrupta* (R. Br.) Beauv.
4. *Paspalum scrobiculatum* Linn. var. *vispicatum* Hack.
5. *Panicum stagninum* Retz.
6. *Panicum distachyum* Linn. and
7. *Panicum repens* Linn.

These grasses are mostly found growing on and along the paddy dikes. The pest was observed to feed mostly on *Panicum carinatum*, which is the most common grass found among the rice plants.

LIFE HISTORY

Materials and methods of study.—The study of the life history of the pest was conducted in the Entomology Laboratory of the Bureau of Plant Industry, Manila. For this purpose, three different containers were used; namely, ordinary test tubes, petri dishes (5 in. x 1 in.), and battery jars (8 in. high and 6 in. diameter).

Larvæ in their cases, collected in Rizal province, were reared in battery jars by feeding them with green leaves of the genus *Panicum*. To keep the leaves as fresh as possible, little water was placed at the bottom of each battery jar. As soon as the adults emerged, couples were picked out and placed in separate petri dishes. Fresh grass and cotton soaked in a sugar solution

were placed in each dish. The cut ends of the grass shoots were wrapped with wet cotton to prevent rapid drying. The grass served as a medium for the insects to deposit their eggs and the sugar solution as food for the adults. In this way, egg laying and the fecundity of the species were observed.

The newly hatched larvæ were separated, and each larvæ was placed in a petri dish. Water and rice seedlings were placed in a petri dish, and were changed daily so as to give the developing larvæ fresh water and leaf throughout their lifetime. The water is about 2 millimeters deep from the bottom of the petri dish. Moltings were recorded in this culture, and as soon as the larvæ pupated, the water in the petri dish was removed and wet cotton was placed instead. The purpose of the latter was to keep the container moist for some time to prevent the pupæ and the rice seedlings from rapid drying. Such a condition is necessary to allow the pupæ to develop into adult. The excess water in the petri dish was removed to prevent the emerging adults from drowning.

Individual rearings were also made in test tubes. By this method the leaves of the rice seedlings were inserted into the test tube and the mouth was loosely closed with cotton to keep the rice stem from moving and at the same time prevent the larvæ from escaping. The root stock which was outside the test tube was wrapped with wet cotton to keep the seedling fresh for some time. A little water was placed inside the test tube where the larva could float. The rice seedling and the water were changed whenever necessary.

There were four sets of individual cultures in petri dishes, two during the month of May, 1935, consisting of eleven individuals, one during June and another one during October of the same year, consisting of six and twenty-four individuals, respectively. Two sets were studied in test tubes. One was during the month of November, 1934, consisting of sixteen individuals and the other during April, 1935, consisting of thirty-one individuals. Mass cultures were in battery jars. Two cultures were under observation in October, 1935.

(*a*) *Period from emergence to egg laying.*—Observations were made on thirty-eight females beginning from the date of emergence. Thirty of these females laid eggs after one to four days with an average of 2.54 days. The records made on these moths are shown in the following table:

TABLE 1.—*Period from emergence of the adults to egg laying.*

Number	Date of emergence	Date first eggs laid	Number of days
	1935	1935	
1	January 2	January 4	2
2	January 3	January 5	2
3	January 4	do	1
	do	January 8	4
4	January 7	January 9	2
	do	January 10	3
6	January 18	January 21	3
7	January 21	January 24	3
8	January 23	January 25	2
9	March 4	March 6	2
	do	March 7	3
10	March 6	March 9	3
14	March 16	March 18	2
15	March 18	March 20	2
19	March 25	March 29	4
21	April 2	April 5	3
22	April 5	April 7	2
23	May 2	May 4	2
24	do	May 5	3
25	May 15	May 17	2
26	May 31	June 2	2
27	June 3	June 3	3
28	do	June 1	2
29	do	June 6	3
30	October 2	October 6	4
31	October 28	October 31	3
32	do	do	3
33	October 29	do	2
34	October 28	do	3
35	October 30	November 1	2
36	do	do	2
37	do	November 2	3
38	October 31	November 2	2
Average			2.54

Minimum ..... 1 day
Maximum ..... 4 days

(*b*) *Incubation period.*—Thirty groups of eggs were laid during the study and only seventeen of them proved to be fertile. They hatched in two to six days with an average of 3.41 days, as shown in Table 2.

(*c*) *Duration of the larval stage.*—Records and observations were made on twenty-four individuals reared successfully in test tubes. The larvæ in these test tubes pupated after 25 to 42 days with an average of 30.62 days, as shown in Table 3. In the case of individual rearings, with the use of petri dishes as containers, the length of the larval stage was very much shorter

TABLE 2.—*Incubation period.*

Culture number	Date eggs laid	Date eggs hatched	Interval
	1934	1934	Days
1	October 17	October 20	3
	1935	1935	
10	March 9	March 12	3
14	March 18	March 22	4
15	March 20	March 23	3
15	do	March 24	4
19	March 29	April 4	6
20	April 3	April 5	2
20	do	April 6	3
21	April 5	April 9	4
22	April 7	April 10	3
22	do	April 11	4
23	May 4	May 7	3
24	May 5	May 9	4
26	June 2	June 4	2
27	June 3	June 6	3
27	do	June 7	4
30	October 6	October 9	3
Average			3.41

Minimum ..... 2 days
Maximum ..... 6 days

as records on 34 individuals show. It lasts from 14 to 20 days only with an average of 15.85 days (Table 4). In the case of the mass cultures in battery jars, the length of the larval stage varied from 15 to 19 days with an average of 16.67 days, as shown in Table 9.

The length of larval stage of those reared in petri dishes and battery jars was about the same, while those reared in test tubes, the length was almost double. This discrepancy in development may possibly be due to the fact that in the test tubes the pest is so confined that its development is greatly retarded.

(*d*) *Duration of larval moltings.*—The larva molts four times before pupation. The duration of larval instars as observed from those individuals reared in test tubes are as follows; first instar larva lasts from four to fifteen days with an average of 9.25 days; the second from four to nine days with an average of 6.75 days; the third from three to nine days with an average of 6.25 days; the fourth from three to ten days with an average of 6.5 days; and the fifth from four to eleven days with an average of 6.12 days. The durations of the different instars in this case are almost twice as those reared in petri dishes (Table 5).

TABLE 3.—*Duration of the larval stage with test tubes as containers.*

Number	Date eggs hatched	Date larvæ pupated	Interval
	1934	1934	Days
2	October 20	November 27	38
4	do	November 14	25
5	do	November 19	30
6	do	December 1	42
7	do	November 14	25
9	do	December 1	42
10	do	November 30	41
13	do	November 20	31
14	do	November 22	33
	1935	1935	
A–1	April 10	May 7	27
3	do	do	27
5	do	May 10	30
6	do	May 12	32
9	do	May 9	29
B–1	April 11	May 8	27
4	do	May 6	25
6	do	do	25
8	do	do	25
10	do	May 9	28
13	do	May 12	31
14	do	May 9	28
16	do	May 7	26
18	do	May 9	28
21	do	May 20	29
Average			30.62

Minimum ..... 25 days
Maximum ..... 42 days

Results obtained from the individual cultures, using petri dishes as containers, show that the first instar larva lasts from two to three days with an average of 2.68 days; the second instar, from two to three days with an average of 2.39 days; the third, from two to three days with an average of 2.43 days; the fourth, from three to five days with an average of 3.3 days; and the fifth from four to six days with an average of 4.78 days (Table 6).

(*e*) *Duration of the pupal stage.*—The length of the pupal, or resting, stage as observed under the three different methods of rearing described varies slightly. In test tubes the duration varied from 5 to 7 days with an average of 5.78 days (Table 7); in petri dishes, from four to seven days with an average of 5.09 days (Table 8); and in battery jars, from five to seven days with an average of six days (Table 9).

TABLE 4.—*Duration of the larval stage in petri dishes.*

Number	Date eggs hatched	Date larvæ pupated	Interval
	1935	*1935*	*Days*
C -1	May 7	May 23	16
2	do	May 22	15
3	do	May 24	17
4	do	May 23	16
5	do	May 25	18
6	do	May 26	19
7	do	May 27	20
D -1	May 9	May 25	16
2	do	do	16
5	do	do	16
6	do	May 24	15
E -2	June 6	June 20	14
3	do	June 22	16
5	June 7	June 23	16
6	do	June 21	14
F -1	October 9	October 25	16
2	do	October 24	15
3	do	October 25	16
4	do	do	16
5	do	October 24	15
7	do	do	15
8	do	October 25	16
9	do	October 26	17
10	do	October 24	15
11	do	October 26	17
12	do	October 25	16
13	do	October 24	15
14	do	do	15
15	do	do	15
16	do	October 26	17
17	do	October 24	15
18	do	October 26	17
19	do	October 24	15
20	do	October 27	18
Average			15.85

Maximum ..... 20 days
Minimum ..... 14 days

(*f*) *Summary of the life cycle from egg to egg.*—The length of the life cycle of the insects that were reared in petri dishes from the time the eggs are laid up to that when the adults begun to lay their eggs is from 21 to 37 days with an average of 26.89 days (Table 10).

(*g*) *Longevity of the adult stage under captivity.*—Under laboratory conditions, the newly emerged adults were placed in petri dishes, two in each, and fed with sugar solution. They began to die two days after confinement, and the longest period

TABLE 5.—*Duration of larval moltings with test tubes as containers.*

Number	Date hatched	Date of first molt	Interval	Date of second molt	Interval	Date of third molt	Interval	Date of fourth molt	Interval	Date pupated	Interval
	1934	*1934*	*Days*	*1934*	*Days*	*1934*	*Days*	*1934*	*Days*	*1934*	*Days*
2	October 20	October 27	7	November 4	8	November 13	9	November 20	7	November 27	7
5	do	October 24	4	October 29	5	November 7	9	November 12	5	November 19	7
6	do	October 30	10	November 7	8	November 12	5	November 20	8	December 1	11
7	do	October 29	9	November 4	6	November 7	8	November 10	3	November 14	4
9	do	October 30	10	November 8	9	November 17	9	November 27	10	December 1	4
10	do	November 4	15	November 10	6	do	7	November 24	7	November 30	6
13	do	October 29	9	November 2	4	November 7	5	November 11	4	November 20	9
14	do	October 30	10	November 7	8	November 10	3	November 18	8	November 22	4
	Average		9.25		6.75		6.25		6.5		6.12

TABLE 6.—*Duration of larval moltings with petri dishes as containers. (Individuals that failed to develop were omitted)*

Number	Date hatched	Date of first molt	Interval	Date of second molt	Interval	Date of third molt	Interval	Date of fourth molt	Interval	Date of pupation	Interval
	1935	*1935*	*Days*	*1935*	*Days*	*1935*	*Days*	*1935*	*Days*	*1935*	*Days*
E-2	June 6	June 8	2	June 10	2	June 12	2	June 15	3	June 20	5
3	do	do	2	June 11	3	June 13	2	June 16	3	June 22	6
5	June 7	June 9	2	June 12	3	June 15	3	June 18	3	June 23	5
6	do	do	2	June 11	2	June 13	2	June 16	3	June 21	5
F-1	October 9	October 12	3	October 14	2	October 17	3	October 21	4	October 25	4
2	do	do	3	do	2	October 16	2	October 20	4	October 24	4
3	do	do	3	October 15	3	October 18	3	October 21	3	October 25	4
4	do	do	3	do	3	October 17	2	October 20	3	do	5
5	do	do	3	October 14	2	October 16	2	October 19	3	October 24	5
7	do	do	3	do	2	do	2	October 21	5	October 25	4
8	do	do	3	do	2	October 17	3	October 20	3	October 26	6
9	do	do	3	do	2	do	3	do	3	October 24	4
10	do	October 11	2	do	3	do	2	October 21	4	October 26	5
11	do	October 12	3	October 15	3	do	3	do	4	October 25	4
12	do	do	3	October 14	2	October 16	2	October 19	3	October 24	5
13	do	do	3	do	2	do	2	do	3	do	5
14	do	do	3	do	2	October 17	3	October 20	3	do	4
15	do	do	3	do	2	October 18	2	October 21	3	October 26	5
16	do	do	3	October 15	3	October 16	2	October 19	3	October 24	5
17	do	do	3	October 14	2	October 18	3	Ocotber 21	3	October 26	5
18	do	do	3	October 15	3	October 16	3	October 19	3	October 24	5
19	do	October 11	2	October 13	2	do	2	October 21	5	October 25	4
20	do	October 12	3	October 15	3	October 18	3	October 22	4	October 27	5
	Average		2.68		2.39		2.43		3.3		4.78

TABLE 7.—*Duration of the pupal stage with test tubes as containers.*

Number	Date larva pupated	Date adult emerged	Interval
	1934	*1934*	*Days*
5	November 19	November 26	7
6	December 1	December 6	5
7	November 14	November 20	6
9	December 1	December 7	6
10	November 30	December 5	5
14	November 22	November 28	6
	1935	*1935*	
A–1	May 7	May 14	7
3	do	May 12	5
5	May 10	May 15	5
6	May 12	May 18	6
9	May 9	May 15	6
B–1	May 8	May 13	5
4	May 6	May 12	6
6	do	do	6
8	do	May 11	5
10	May 9	May 15	6
13	May 12	May 17	5
14	May 9	May 16	7
18	do	May 15	6
Average			5.78

Maximum ..... 7 days
Minimum ..... 5 days

that an adult was observed to live under such condition is eight days. It was noted, however, that before the females died, they had laid on the average more than one-half of their eggs. The following table shows the records obtained from twenty-five individuals.

HABITS

(*a*) *Adult.*—The adults are nocturnal in habit and are attracted to house lights at night. During the day, they hide under the leaves of rice and grasses, oftentimes in association with the adults of the rice leaf-folder, (*Cnaphalocrosis medinalis*) and fly readily when disturbed. When the adult is at rest the wings are expanded and are pressed against the object where it rests, as a leaf, for example. In no instance was copulation observed during the day either in the field or in the laboratory. So it is presumed that mating takes place only during the night.

Egg laying also takes place at night, the eggs being deposited on the lower surfaces of the leaves as well as on the stems of rice and grasses just a little above the surface of the water. In the field, eggs have also been observed on floating empty leaf cases of the worms. They are placed in rows of one or two,

TABLE 8.—*Duration of the pupal stage with petri dishes as containers.*

Number	Date larva pupated	Date adult emerged	Interval
	1935	*1935*	*Days*
C–1	May 23	May 30	7
3	May 24	do	6
4	May 23	do	7
5	May 25	May 31	6
6	May 26	do	5
7	May 27	June 1	5
D–1	May 25	May 30	5
2	do	May 31	6
5	do	do	6
6	May 24	do	7
E–2	June 20	June 25	5
3	June 22	June 27	5
5	June 23	June 29	6
6	June 21	June 26	5
F–1	October 25	October 30	5
2	October 24	October 29	5
3	October 25	October 31	6
4	do	October 29	4
5	October 24	October 28	4
7	do	October 29	5
8	October 25	October 30	5
9	October 26	do	4
10	October 24	October 29	5
11	October 26	October 30	4
12	October 25	do	5
13	October 24	October 28	4
14	do	October 29	5
15	do	do	5
16	October 26	October 30	4
17	October 24	October 28	4
18	October 26	October 30	4
19	October 24	October 29	5
20	October 27	October 31	4
Average			5.09

Maximum ..... 7 days
Minimum ..... 4 days

TABLE 9.—*Life cycle in mass culture with battery jars as containers.*

Date eggs laid	Date eggs hatched	Interval	Date larva pupated	Interval	Date adults emerged	Interval	Total number of days	Number of individuals
1935	*1935*		*1935*		*1935*			
			Culture No. 1					
Oct. 4	Oct. 7	3	Oct. 23	16	Oct. 30	7	26	
			Oct. 24	17	Oct. 31	7	27	8
			Oct. 26	19	Oct. 31	6	28	
			Culture No. 2					
Oct. 9	Oct. 11	3	Oct. 26	15	Oct. 31	6	24	
			Oct. 27	16	Nov. 2	6	24	11
			Oct. 28	17	Nov. 2	5	25	
Average		3		16.67		6	25.5	

TABLE 10.—*Summary of life cycle from egg to egg.*

Stage of the pest	Duration in days	Average number of days	Remarks
Egg stage	2 to 6	2.41	Reared in petri dishes.
Larval stage	14 to 20	15.85	Do.
Pupal stage	4 to 7	5.09	Do.
Emergence of adult to egg laying	1 to 4		Do.
Total	21 to 37	26.89	

TABLE 11.—*Longevity of the adult stage under captivity.*

Individual number	Date emerged	Date died	Interval	Sex
	1935	*1935*	*Days*	
1	January 2	January 5	3	Female.
2	January 3	do	2	Male.
3	do	January 7	4	Female.
4	January 4	January 10	6	Male.
5	do	do	6	Female.
6	January 7	January 12	5	Male.
7	do	do	5	Female.
8	January 10	January 14	4	Male.
9	do	do	4	Female.
10	January 26	January 29	3	Female.
11	do	do	3	Male.
12	do	January 30	4	Female.
13	October 28	October 4	7	Do.
14	do	October 5	8	Do.
15	do	October 2	5	Do.
16	do	do	5	Do.
17	October 29	October 4	6	Male.
18	do	do	6	Do.
19	do	do	6	Female.
20	do	October 2	4	Do.
21	October 30	October 4	5	Male.
22	do	do	5	Do.
23	do	do	5	Female.
24	do	October 3	4	Do.
25	do	October 5	6	Do.
Average			4.8	

Maximum ..... 8 days
Minimum ..... 2 days

numbering to as many as twenty-one. In the laboratory they were found laid without any definite arrangement on the sides of the containers where they were kept in confinement. In most cases the females laid their eggs all at once during their lifetime, but a few individuals were observed to have laid their eggs at two different times before they died (see Table 12).

(*b*) *Larva.*—The larvæ commence to feed on the same day they hatch, and after two days they begin to enclose themselves

in cases out of the young leaves of rice or grasses, as the case may be. On rice, a caterpillar crawls up to about the tip of young rice leaf and cuts the upper end. It then turns back, facing downward, and begins to fold both edges of the leaf with its silklike threads. As soon as the leaf is completely folded, it cuts the bottom end of the folded portion until the case, or covering, thus formed is severed from the leaf. It holds the leaf with its legs having its head and thorax out of the case and hangs in a slanting position. When casing is done on grass with short leaves, the caterpillar selects a leaf suitable to its length and folds the leaf without further cutting the tip. After this is done, the bottom end, right at the base of the leaf, is then severed. There are several ways by which the caterpillar incloses itself in a leaf but the two described above are the most common.

The larva molts four times, from hatching to pupation, and it also changes its case the same number of times, each change taking place before each molt. When full-grown, the larvæ with their cases, or coverings, lodge on the stems of the rice plants or on any other objects just a little above the surface of the water. The cases are first attached to the stem of rice or any other objects parallel to the latter with their silky threads through a little opening at about the middle of the cases. They then pupate inside (Plate 3, fig. 1). The adults emerge from these cases during night coming out through an opening at the upper end.

c. Number of eggs laid by each female.—The females under observation in the laboratory laid from 3 to 103 eggs during their lifetime, with an average of 52.2. However, after the females died, they were dissected, and the developed eggs in their ovaries were counted. From 0 to 93 eggs were found, with an average of 28.9. Taking the total of the laid and unlaid eggs, each female may have a laying capacity, under field conditions, of from 47 to 103 eggs with an average of 81.1. Table 12 shows the records obtained from the ten females understudy.

(*d*) *Sexual ratio.*—The number of adult males and females was counted as they emerge from larvæ that were reared in the mass cultures. Those that emerged from the individual cultures were likewise counted. It was observed that out of the 159 adults counted, 84 were males and 75 were females, or there was a ratio of 50 to 45 in favor of the males. In nature the sexual ratio is about equal (Table 13).

TABLE 12.—*Fecundity.*

Female number	Date of first laying	Number of eggs	Date of second laying	Number of eggs	Total laid	Date died	Number of developed eggs counted after dissecting	Total number of eggs laid and unlaid
	1935		*1935*			*1935*		
1	Jan. 4	3			3	Jan. 6	69	72
2	Jan. 5	38			38	do	36	74
3	do	22	Jan. 8	7	29	Jan. 9	33	62
4	Jan. 9	25	Jan. 10	13	38	Jan. 10	9	47
23	May 4	97			97	May 5	0	97
24	May 5	40			40	May 6	23	63
27	June 3	67			67	June 10	26	93
28	June 1	9			9	June 2	93	102
36	Nov. 1	68	Nov. 2	30	98	Nov. 4	0	98
37	Nov. 2	77	Nov. 3	26	103	do	0	103
	Average	44.6		7.6	52.2		28.9	81.1

Minimum number of eggs laid 3
Maximum number of eggs laid 103

(*e*) *Prevalence.*—From the month of July to November, the caterpillars are abundant and feed on the leaves of rice plants and grasses growing in the paddies. During these months the leaves of rice are still soft and tender and are, therefore, very susceptible to their attack. From the month of November to July of the succeeding year, they breed on grasses growing in the rice fields and in other places where there is always water, as springs, pools, etc. The names of some of these grasses where they breed during the dry season are given under the heading "host plants" discussed elsewhere in this paper. The broods overlap as different stages were observed at different times of the year. These observations on the prevalence of the pest were made in the province of Rizal from October, 1934 to June, 1936. It is most likely that the same observations apply to a more or less extent in other provinces where lowland rice is planted during the months of June and July.

DESCRIPTION

Egg.—Circular, somewhat flattened, light yellow, and has a smooth surface. Its diameter is about 0.5 of a millimeter. A day before hatching, the color becomes darker and two purplish dots appear, representing the eyes of the developing larva (Plate 2, figs. 1 and 2).

TABLE 13.—*Proportion of males to females.*

Date emerged	Number of males	Number of females	Remarks
1934			
December 11		1	Adults emerged from larvæ collected from the field.
December 12	1	2	
December 13	2		
December 16	1	1	
November 20		1	Adults reared from individual cultures.
November 26		1	
November 28	1		
December 5	1		
December 6	1		
December 7		1	
1935			
January 8	1	1	Adults reared from larvæ collected from the field.
January 10	1	1	
January 16		3	
January 17	2	2	
January 18	3	5	
January 21	8	7	
January 22	6	1	
January 23	3	4	
January 25	2	3	
January 26	2	2	
January 31	5	3	
March 4	3	3	
March 16	3	2	
March 18	6	3	
March 19	4	4	
March 20	3	2	
May 11	1		Adults from individual cultures.
May 12	1	2	
May 13	1		
May 14	1		
May 15	2	2	
May 16		1	
May 17	1		
May 18	1		
May 30	1	3	
May 31	1	3	
June 25	1		
June 26	1		
June 27	1		
June 29	1		
October 28		4	
October 29	6	2	
October 30	4	3	
October 31	1	2	
Total	84	75	

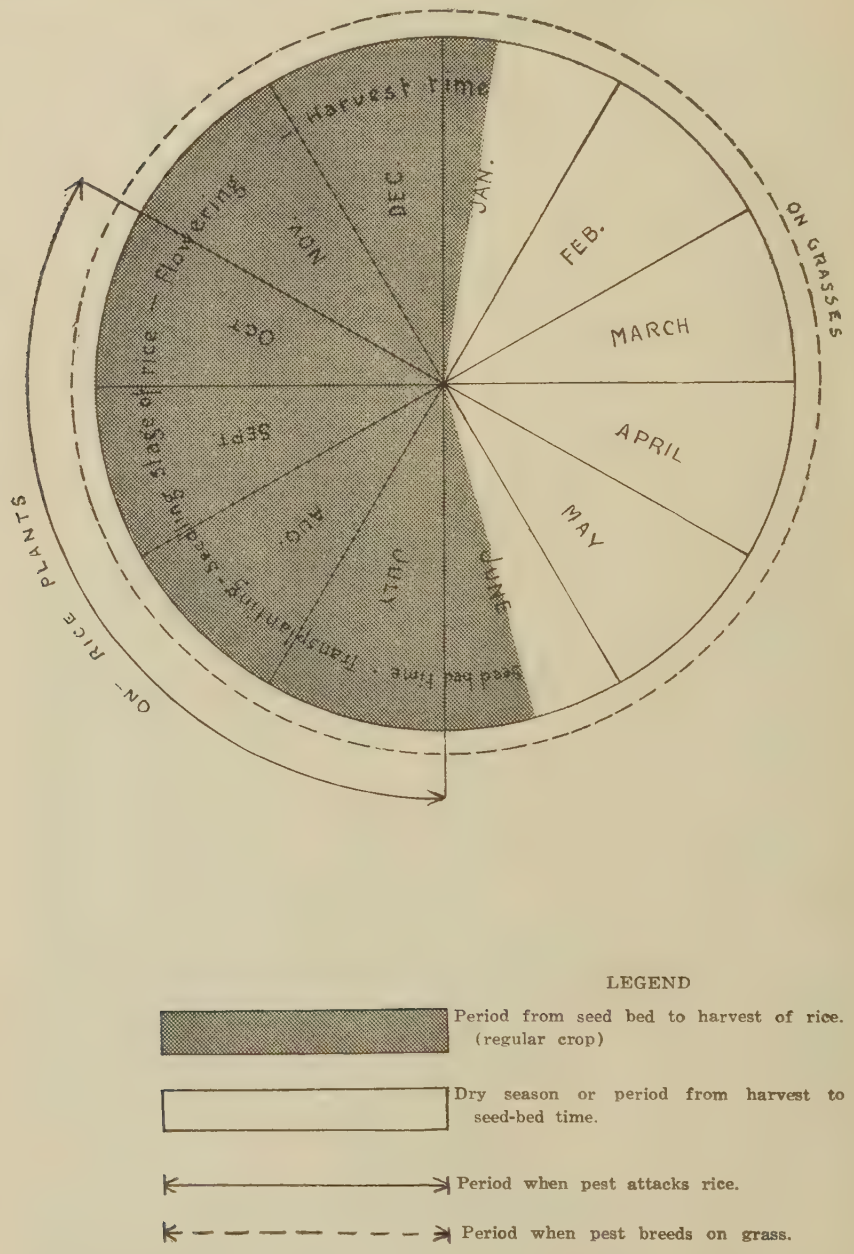

FIG. 1. Diagram showing the occurrence of the pest (*N. depunctalis*) throughout the year as observed in the Province of Rizal.

First instar larva.—About 1.2 millimeters long and 0.2 millimeter in diameter across the head; when newly hatched, it has a pale-cream color. The head is light yellow including the first thoracic segment and the eyes and mandibles are light purple. There are thirteen segments. The body is semitransparent, the tracheal tubes and tubular gills being visible with the aid of a magnifying glass. The head and first thoracic segment are sparsely covered with short hairs, or setæ (Plate 2, fig. 3.)

Second instar.—About 2.5 millimeters long and 0.5 millimeter in diameter across the middle of the body when newly molted; greenish throughout. The head is a little smaller than the body and light yellow. The markings, segmentation, and other characters are similar to those in the first instar.

Third instar.—About 5 millimeters long and 1 millimeter wide at its greates width. The color and markings are similar to those in the second instar. The tracheal tubes are longer than the third instar. The head, the first thoracic segment, and the anal segment are sparsely covered with short hairs.

Fourth instar.—About 8 millimeters long and 1.5 millimeters wide at its greatest width. The color and markings are similar to those in the third instar.

Full-grown larva.—About 14 millimeters long and 1.6 millimeters in diameter, pale green and somewhat transparent. The alimentary tract is green, and its contents are visible through the semi-transparent skin along the middle portion of the body. The head is about a millimeter in diameter, light brown including the first thoracic segment, and both parts are with brown spots. Both are sparsely covered with short hairs, or setæ. There are thirteen distinct segments, and the body is characterized by the presence of six rows of thin gills with tubes connected to the main trachea. There are five pairs of spiracles which, according to Maxwell-Lefroy (1909), are functionless, because the larvæ use the thin gills as breathing organs, instead (Plate 2, fig. 4).

Pupa.—About 5.5 millimeters long and 1.5 millimeters at its greatest diameter, and is creamy when newly pupated. The head is about 1 millimeter in diameter, and the developing eyes are purplish. Across the middle portion of the body, the diameter is about 1.5 millimeters. There are eight distinct abdominal segments with three pairs of prominent brown spiracles (Plate 2, figs. 7 and 9). The color of the pupa changes after the second

day, the eyes becoming ashy and the thoracic region, the wing pads, the legs, and the abdomen, silvery white. Antennæ, golden. Abdominal sutures are light yellow. The short and black hair-like projections are present at the anterior of the head.

ADULT

Female adult.—About six millimeters from the tip of the head to the tip of the abdomen, and has a wing expanse of from 15 to 16 millimeters. The general color is white with light brown and black markings on the wings.

The antennæ are about three millimeters long extending backwards, and rest on the wings. When the insect is at rest both pairs of wings are fully spread, or expanded. (Plate 3, fig. 1). Figure 3 in the same plate is the ventral view of the posterior abdominal segments of the female.

Male adult.—The male is usually smaller than the female, measuring from 4 to 5 millimeters from the tip of the head to the tip of the abdomen, and has a wing expanse of from 11 to 14 millimeters. Dorsally, the color and markings are practically similar to those of the female. Ventrally, including the last pair of legs, the color is darker than the corresponding part in the female. (Plate 2, fig. 2.) Figure 4, Plate 3 shows ventrally the posterior abdominal segments of the male.

Hampson (1896) describes the adult in detail as follows:

> Pure white. Forewing with the costa dark; a dark speck on a fulvous spot below middle of cell; a fulvous spot below origin of vein; 2 two black discocellular specks; an oblique fulvous band beyond the cell from costa to vein 5; a submarginal fulvous band, narrowing below vein 5, or often reduced to specks and obsolescent. Hind wing with dark discocellular speck, sinuous medial and post medial fulvous with a fine crenulate fulvous or dark-brown line just inside the margin and a more or less developed marginal series of specks.

NATURAL ENEMIES

The adult moths which fly at short distances among rice and grasses are often caught in spiders' webs or by birds and dragon flies. The circumstance minimizes the infestations to a certain extent.

The larvæ are parasitized by certain species of hairworms, possibly a species of the Family Mermithidæ (Plate 4, fig. 1). The mermithids live inside the body of the larvæ, while the latter are alive (Plate 4, fig. 2) ; but as soon as the contents of the hosts are consumed, the parasites leave the hosts and stay in the paddy water. The larvæ which are attacked by the hairworm never

develop into the pupal stage. Counts, made of the number of larvæ having the mermithid parasite under field conditions, show that out of the 28 individuals examined on October 20, 1935, 3 were parasitized. This gives a parasitism of 10.71 per cent. On October 31, 1935, another count was made and out of the 94 larvæ examined, 12 were parasitized, or a parasitism of 12.73 per cent. Seven more observations were made during the month of November, 1935 and the parasitism was from 2.63 per cent to 6.45 per cent. These percentages of parasitism give an average of 6.37 per cent (Table 14).

TABLE 14.—*Parasitism of rice caseworm larvæ by the hairworm.*[a]

Date	Examined	Not parasitized	Parasitized	Percentage of parasitism
1935				
October 20	28	25	3	10.71
October 31	94	82	12	12.73
November 5	16	15	1	6.25
November 5	31	30	1	3.22
November 5	33	31	2	6.06
November 6	38	37	1	2.63
November 7	31	29	2	6.45
November 10	22	21	1	4.54
November 10	21	20	1	4.75
Average				6.37

[a] Only larvæ with visible parasites were counted as parasitized.

The maggot (Plate 4, fig. 3) of a species of *Tabanus* fly (*Tabanus* sp.) was also observed feeding on the larvæ of the pest while the larvæ were in their cases (Plate 4, fig. 4).

So far, no egg parasite has been observed under field conditions, but in the laboratory, the imported parasite, *Trichogramma minutum* Riley, was tried on the eggs of *Nymphula depunctalis*. The parasites were observed to oviposit on the eggs thus exposed, and they turned black three days after the exposure, like other eggs attacked by the same parasite. No adult parasites were able to emerge, because the eggs dried up in the test tube. Unparasitized eggs of *N. depunctalis* never became black even if they did not hatch.

The common red ants (*Solenopsis geminata*) which build their nests in the paddy dikes attack the larvæ and pupæ of the pest, especially when the infested paddies became dry.

Prolonged drying up of the paddies is detrimental to the larvæ, and after strong rains and wind, the adult moths were often seen dead and floating on the water in rice paddies.

FIELD CONTROL TRIALS

(*a*) *Effect of draining the water from the infested paddies, application of kerosene on the paddy water, and dusting the leaves with calcium arsenate upon the larvæ.*—On October 16, 1935, four paddies which had almost the same degree of infestation were selected in the municipality of Binañgonan, Province of Rizal. The rice leaves of the first paddy were dusted with calcium arsenate including those of grasses growing among the rice plants. The powder was placed inside a cheesecloth bag. Then it was jarred slightly over the rice plants, and portion of the powder that escaped from the bag, adhered to both surfaces of the leaves. The use of cheesecloth bag in this particular case was possible to dust the nether surfaces of the leaves because the infested seedlings had their leaves almost straight upward as their tips were cut. (Plate 1). The second paddy was treated with kerosene by pouring it little by little on the water at the place where the water enters the paddy; the third was drained of its water; and the fourth was left untreated to serve as control. Leaf cases, supposed to contain larvæ were collected at random every day from the treated paddies and from the control. They were examined, and the number of dead larvæ were counted, discarding those that were parasitized and the leaf cases that were empty. The percentage of dead larvæ was computed from each set to determine the comparative degrees of mortality due to the effect of the different treatments. Observations were made for only two days, because it rained on the third day.

On November 3, 1935, another field trial was conducted in a different place. The same procedure was followed and partial result was likewise obtained, because rain affected again the experiment on the fourth day.

The results, obtained as presented on Table 15, show that the drained fields, as per counts done daily, had a mortality ranging from 30 per cent to 62.5 per cent with an average of 49.22 per cent. In the case of those paddies treated with calcium arsenate, the percentage of death from the daily observations ranged from 12.9 per cent to 63.88 per cent with an average of 31.65 per cent, and in the kerosene, treated paddies, the deaths ranged from 6.67 per cent to 64.28 per cent with an average of 23.06 per cent.

TABLE 15.—*Deaths of rice caseworm larvæ observed daily on the different treatments.*

Date of observation	Kind of treatment	Examined	Dead	Per cent
1935				
October 17 [a]	Water drained	90	48	53.33
October 18 [a]		89	54	60.67
November 4 [b]		20	6	30.00
November 5 [b]		16	10	62.50
November 6 [b]		38	18	47.36
November 7 [b]		41	17	41.46
Average				49.22
October 17 [a]	Cal. arsenate	30	13	43.33
October 18 [a]		36	23	63.88
November 4 [b]		16	4	25.00
November 5 [b]		33	9	27.27
November 6 [b]		40	7	17.50
November 7 [b]		31	4	12.90
Average				31.65
October 17 [a]	Kerosene	43	8	18.60
October 18 [a]		14	9	64.28
November 4 [b]		14	1	7.14
November 5 [b]		15	1	6.67
November 6 [b]		32	8	25.00
November 7 [b]		12	2	16.66
Average				23.06
October 17 [a]	Control	46	4	8.69
October 18 [a]		42	2	4.76
November 4 [b]		23	1	4.34
November 6 [b]		31	1	3.22
Average				5.22

[a] First trial, begun October 16. [b] Second trial, begun November 3.

The control paddies had a mortality of from 3.22 per cent to 8.69 per cent with an average of 5.22 per cent. Comparing the result obtained from the control paddies with the treated ones, the drained fields on the average daily counts had a mortality of 44 per cent over control; calcium arsenate 26.43 per cent and kerosene 17.74 per cent. The kerosene and calcium arsenate did not produce any burning effect on the rice plants.

Although the trials were disturbed by rains on the third day of the first trial and on the fourth day of the second—a factor which cannot be controlled under field conditions—yet the results obtained are encouraging on the ground that the treated fields gave a fairly good mortality over the control.

(*b*) *Approximate cost of application computed to a hectare.*—For the purpose of obtaining information on the approximate

expense that they may be incurred in the application of the above-named methods, the following computation is herewith presented;

(1) *Calcium arsenate.*—About 300 grams of this chemical were used in treating an area of about 100 square meters of three-week old rice plants planted about 15 centimeters apart. Basing on this quantity of calcium arsenate powder consumed to cover the said area, about 30 kilos of the chemical will be needed to dust one hectare. At the rate of thirty centavos (₱0.30) a kilo of calcium arsenate, the approximate cost of the chemical necessary for one application will be about nine pesos (₱9.00). Adding the cost of the four-hour labor which is forty centavos (₱0.40) at the rate of eighty centavos a day, the total expense will be nine pesos and forty centavos (₱9.40) a hectare.

(2) *Kerosene.*—About 150 cubic centimeters of kerosene were used on a paddy having an area of about 35 square meters. With this quantity, only a very thin film of the oil was formed over the surface of the water. Basing on this application, one hectare will require about 47 liters or about two and a half cans of five gallons each. The price of a five-gallon can of kerosene (Carabao brand) in the market was ₱1.80 at the time of the experiment so that the kerosene consumed cost about ₱4.62. Adding the cost of two-hour labor, which may be estimated at twenty centavos (₱0.20), the application cost about ₱4.82.

TRIALS WITH DERRIS ("TUBLE") POWDER UNDER LABORATORY CONDITIONS

Otanes(10), in mentioning the use of fresh derris roots againts rice stem borer (*Schoenobius incertellus*) in the Visayan Islands, Philippines, also suggested the possibility of the use of the same against the rice caseworm, *Nymphula depunctalis*.

Because of the availability of derris powder (this being manufactured by the Bureau of Plant Industry from the roots of derris plants, *Derris elliptica*) laboratory tests against the larvæ of *Nymphula depunctalis* was made possible. Derris is locally known as tuble, and the roots are used in the Islands and elsewhere for poisoning fish. The plants grow wild here, and up to this writing some farmers have started extensive plantings for commercial purposes.

The trial consisted as follows: Larvæ with their cases were collected from the field and placed in three separate containers with water having a volume of about 200 cubic centimeters each

and a surface area of about .11 square meter. Grass was also placed in each container. In the first container 22 larvæ were placed and 25 each in the second and the third containers. The first container was dusted with derris powder amounting to 0.2 gram; in the second 0.13 gram was used; in the third, 0.1 gram. The dust covered the surface of the water. With the 0.2 gram, all the larvæ died after about five hours, while in the last two treatments, it took about 22 hours before all the larvæ died.

In another trial the derris powder was put in the water after which the whole was stirred well before the larvæ were placed so as to get readily the soluble substance from the powder. The strengths used were 0.1 gram and 0.05 gram per liter of water. Twenty larvæ were used in each case. In the first application, all the larvæ died after about four hours and in the second, after about five hours. The derris powder used in all the above trials had a rotenone content of 3.09 per cent according to the analysis made by the Plant Utilization Division of the Bureau.

SUMMARY

The rice caseworm, *Nymphula depunctalis* Guen, (Family Pyralidæ) is one of the most important rice pests in the Philippines, and causes more or less serious damage. It attacks rice from July to November. From November up to the planting of the next crop, it feeds on grasses growing in water in the rice fields, in springs, pools, ponds, lakes, etc. Among the species of grasses where they were observed to feed on are *Panicum carinatum, Panicum colonum, Eragrostis interrupta, Paspalum scrobiculatum,* var. *vispicatum, Panicum stagninum, Panicum distachyum,* and *Panicum repens.* These grasses are common in rice fields in the Philippines.

Under laboratory conditions, the females laid eggs in one to four days after emergence, and the number of eggs laid by one female ranged from 3 to 103 with an average of about 52. However, when the females under observation died and were dissected, eggs were observed in their ovaries, the number ranging from 0 to 93. This gives the range of eggs produced from 47 to 103 with an average of about 81.

In this work, the eggs were observed to hatch after two to six days. After feeding for a day or two, the young larvæ were observed to enclose themselves with cases out of pieces of rice or grass leaves. The larvæ molted four times before pupating, each larva changing its leaf case usually before each molting.

The larval stage lasted from 14 to 20 days, with an average of 15.85 days. The pupal stage lasted from four to seven days, with an average of about five days.

The life cycle of the pest from egg to egg, under laboratory conditions, varied from 21 to 37 days, with an average of about 27 days.

The larvæ are attacked by a certain species of hairworm possibly of the Family Mermithidæ, with a parasitism of from about 3 to 13 per cent as observed in the field. The larvæ are likewise attacked by the maggot of a species of Tabanus fly and by the red ants (*Solenopsis geminata*).

Dusting the infested plants with calcium arsenate, draining the water from the infested paddies, and applying a thin film of kerosene over the water to control the larvæ gave encouraging results. Preliminary trials, under laboratory conditions, with derris powder also gave encouraging results, so that further trials in the laboratory and in the field are warranted.

ACKNOWLEDGMENT

The writer wishes to express his appreciation to Dr. Gonzalo Merino and Mr. F. Q. Otanes, Chief and Asst. Chief, of the Plant Pest and Disease Control Division, respectively, for their valuable suggestions and criticism while the work was in progress.

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ILLUSTRATIONS

Plate 1

Fig. 1. Rice plant showing the nature of damage done by the larvæ of rice case worm. (*a*) Papery membrane left on the leaf as a result of the injury; (*b*) larva with its leaf case; (*c*) leaf case attached to the stem of rice plant wherein the larva pupates; (*d*) floating leaf case with larva inside. (× 10)

Plate 2

Fig. 1. Grass shoot with eggs. (About natural size).
2. Egg much enlarged.
3. Newly hatched larve. (× 10)
4. Full-grown larva, lateral view. (× 10)
5. Full-grown larva, ventral view. (× 10)
6. Full-grown larva, ventral view. (natural size)
7. Pupa, ventral view. (× 10)
8. Pupa, ventral view. (natural size)
9. Pupa, lateral view. (× 10)
10. Pupal case showing opened portion where it is attached to the rice stem. (× 10)
11. Same (natural size)

Plate 3

Fig. 1. Adult female, dorsal view. (× 10)
2. Adult female, dorsal view. (natural size)
3. Adult male, dosal view. (× 10)
4. Adult male, dorsal view. (natural size)
5. Posterior end of female's abdomen showing anal segment. (× 10)
6. Posterior end of male's abdomen showing anal segment. (× 10)

Plate 4

Fig. 1. The mermithid (hairworm) parasite after it has emerged from the host. (× 10)
2. A larva, dorsal view, showing the mermithid parasite inside its body. (× 10)
3. The maggot of a species of Tabanus fly that preys upon the larva. (× 10)
4. Dead larva attacked by the predatory maggot. (*a*) Empty larva of the caseworm; (*b*) the predatory maggot. (× 10)

Text figure

Fig. 1. Diagram showing the occurrence of the pest (N. depunctalis) throughout the year as observed in the Province of Rizal.

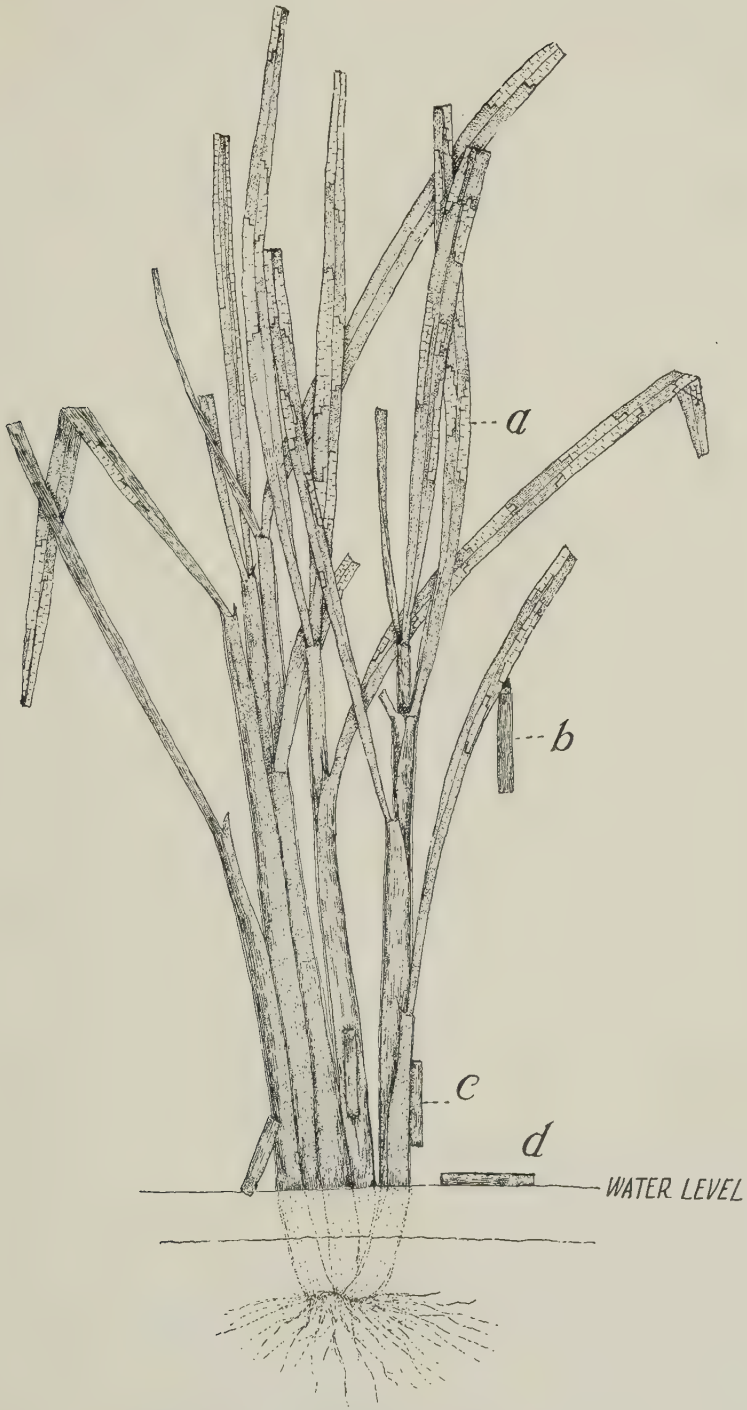
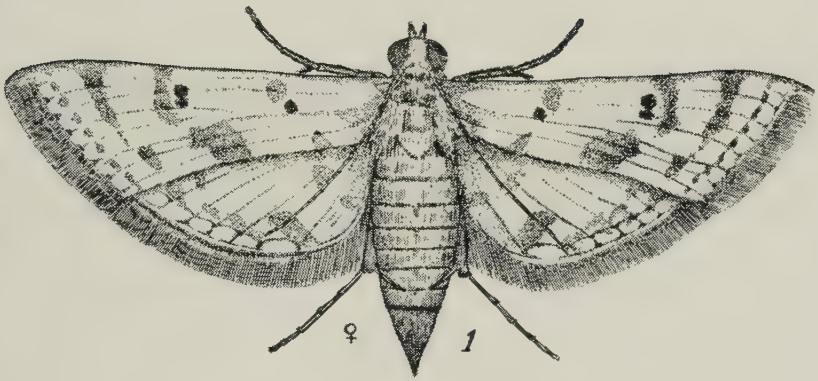


PLATE 1.

PLATE 2.



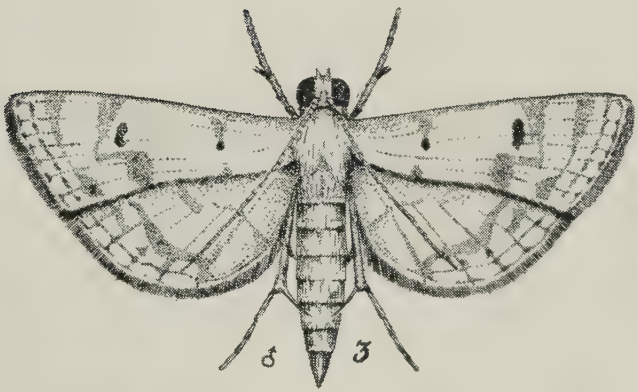


PLATE 3.

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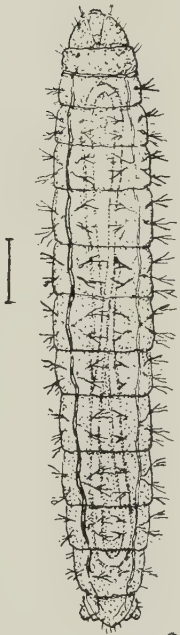

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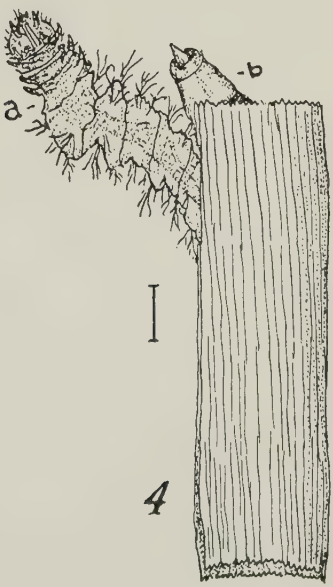

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PLATE 4.

NOTES ON THE HANDLING OF LANZON FLOWER BUDS AT HARVEST TIME

By Salustiano S. Gonzales and Filemon Abaya
Of the Bureau of Plant Industry

FOUR PLATES

Up to the present time, the flower buds of the lanzones are the forgoten parts of the tree to most people insofar as care is concerned. A great number of these buds are destroyed by the notorious lanzon bark borers in almost all regions where the tree is grown. Still more buds are destroyed during harvests, for the simple reason that their presence on the tree at such a time is unknown to most of those concerned.

This article was thought of after several observations on the lanzon and on the methods of harvesting its ripe fruits in connection with a study now in progress on the control of the lanzon bark borers. The observation is of great importance especially when it is considered that the primitive method of gathering the fruits adversely affects future production, particularly the following crop, and as such the results of our study on the effect of the bark borers and that of the treatment given the trees to prevent future bark borer infestations on the trees' production, will be very much modified.

These notes, therefore, aim to acquaint those concerned with some facts about the lanzon flower buds and how their mechanical destructions may be minimized or completely averted especially during harvests.

THE LANZON FLOWER BUDS

The lanzon flower buds may appear singly or in groups of from 2 to 9. Each bud appears as a reticulate minute structure on the main trunk or branches of the trees either around the bases of the bunches of maturing fruits or on new locations. During the harvest season, most of those buds for the following or still later year's crop are about the size of a pinhead (Plate 1, fig. 2). Others may then be very much bigger, and if carefully examined, can be located without difficulty (Plate 1, fig. 2). These flower buds may develop earlier if weather conditions are

favorable or if there is a continuous supply of moisture especially during the dry season. Sometimes, also, depending upon weather conditions, many of the flower buds, especially those appearing before the dry season, either dry out or remain dormant for still another year.

Causes of destruction.—Although numerous flower buds are continuously being destroyed by the lanzon bark borers [1] throughout the year, more buds meet the same fate during harvests but from a different cause. We refer to the current methods of harvesting the fruits.

Orgas [2] gave warning about the manner of harvesting the crop, stating that in picking, the matured fruits should not be pulled off, as it injures the portion to which the bunch is attached and because it is within this region where the second set of fruits develops. He suggested that a sharp knife or shears should be used in clipping off the bunches. Many harvesters have already employed this improved method of harvesting the fruits, although there are still some who cling to the old practice of merely pulling off the bunches, thereby actually destroying the flower buds for the next crop which often are already visible at the bases of the bunches of mature fruits (Plates 2 and 3).

But a still greater injury to the following crop is generally done during harvests when the harvester climbs the tree with his hands and legs unaware of the numerous flower buds situated here and there on the trunk and on the upper portions of the tree, thus destroying many of these undetected future crops which, as has been stated above, are already visible during the months of harvests (September and October) particularly those that are around the bases of the clusters of fruits to be harvested.

The destruction of these flower buds will naturally result in less production the following year or season. Slipping of the feet and hands of the harvester during harvests or even their mere pressure are enough to destroy or completely detach these minute flower buds from the trees. This partly explains the common belief of lanzon grove owners that a year of good harvest is generally followed by a year of poor harvest. When the tree bears fruit heavily, the harvester naturally stays in the tree

[1] A separate study on the lanzon bark borers is now being undertaken by the senior writer and another report covering this topic will be made as soon as results are complete.

[2] Orgas, Adriano M. The Lanzon (*Lansium domesticum* Jack). P. I. Dept. of Agriculture and Commerce. Bureau of Plant Industry Farmers' Circular No. 6.

longer than when the tree has few fruits. The more he moves about from branch to branch, the more are his chances of destroying the buds which will naturally result in small crop the following year; and because the trees will have only few or no buds to develop, so very few or no fruits at all will be harvested the following season. It follows then that the harvester should either stay in the tree only for a very short time and perhaps move less, or that he should not climb the tree at all, with the result that the trees are relieved of the usual ordeal it has to pass during harvest of good crops. The buds that are beginning to form at this time of the year will then have a good chance to develop for the next season.

RECOMMENDATIONS

To avert, therefore, this contributing factor, in the failure of the trees to produce normal crops every year, it would be well to eliminate, as much as possible, direct contact of the harvester with the trunk and the bearing branches of the trees during harvest time. This can be done by using ladders, preferably a portable self-supporting ladder as shown in Plate 4, when gathering the fruits. This will minimize or completely do away with the necessity for the harvester to step on the trunk or branches of the trees, thus saving the buds that would otherwise be destroyed if the fruits are gathered without the use of the ladder.

As was pointed out, the bunches should be clipped off with a sharp curved knife like the pruning knife or a shear, not merely detached with the bare hands. These suggested methods of harvesting are being employed in our bark borer control experiments with gratifying results.

ILLUSTRATIONS

PLATE 1

FIG. 1. A developing flower bud.
2. A cluster of flower buds.

PLATE 2

A developed flower bunch with flower buds at its base.

PLATE 3

A bunch of mature fruits with developing flower buds at its base.

PLATE 4

A portable self-supporting ladder that should be used in harvesting the fruits.

1

2

PLATE 1.

PLATE 2.

PLATE 3.

PLATE 4.

TRANSMISSION EXPERIMENT OF ABACÁ MOSAIC
(Progress Report No. 1)

By MELANIO R. CALINISAN

Of the Division of Plant Pest and Disease Control, Bureau of Plant Industry

THREE PLATES

In 1933, the writer(1) first observed the occurrence of the mosaic disease on abacá (*Musa textilis* Née) in the Province of Davao, Philippines. At first the disease appeared rather insignificant and no authentic report of its occurrence was known. Since 1933, however, it developed into one of the major diseases of abacá. The present paper includes the results of the transmission studies from diseased to healthy plants. Experiments were performed in the greenhouse of the Plant Pathology Laboratory, Bureau of Plant Industry, Manila, Philippines.

TRANSMISSION EXPERIMENTS

1. *Through soils.*—(*a*) On November 2, 1933, a series of experiments were conducted to determine if the abacá seedlings planted in "sick" [1] soil would develop the mosaic disease. Negative results were obtained.

(*b*) Similar experiment was performed by planting healthy abacá seedlings in sterilized garden soil mixed with decomposed mosaic tissues of abacá plant. Negative result was also obtained.

2. *By contact with diseased and healthy roots.*—(*a*) On November 3, 1933, healthy abacá seedlings, two months old, were planted in the same pot with mosaic plants in such a way that their roots were intertwined and in close contact with each other. Three healthy abacá seedlings and one diseased plant were planted in each of the four pots. After planting, all pots were covered with cheesecloth to exclude insects. No transmission of abacá mosaic was obtained after six months.

(*b*) *By contact with the leaves of healthy and mosaic plants.*—Three potted healthy abacá seedlings and three potted mosaic-infected plants were placed side by side in pairs in such a way

[1] "Sick" soil is meant soil taken from around and under the base of mosaic-infected abacá plant. This soil was taken from Davao.

that the healthy plant was paired with a diseased abacá. The leaves of the healthy plant were allowed to be in contact with the leaves of the mosaic-infected plant and rub each other periodically. This experiment was repeated in a series of trials. The result was negative.

4. *Through seeds.*—The writer failed to produce mosaic-infection by soaking for different lengths of time, seeds and seedlings of healthy plants, in diluted and undiluted juice expressed from the leaves, stems, corms, and roots of a mosaic abacá.

5. *Inoculations on the leaves.*—Goeffrey(3) used flat glass spatulas with success in his work entitled, "Some Experiments on Inoculating Methods with Plant Viruses and on Local Lesions." In an attempt to transmit the abacá mosaic disease to healthy plants the same procedure employed by Goeffrey was closely followed by the writer but negative result was obtained.

(*b*) Another method of artificial inoculation on the leaves which Fajardo(2) claims has given him a very high percentage of infection in his bean mosaic was also adopted. The method used consists of rubbing the upper surface of the abacá leaves with a small piece of cheesecloth containing a small quantity of sterilized fine sand mixed with a ground mosaic tissue until a more or less uniform abrasion is produced. Not a single case of mosaic infection developed.

(*c*) Another method employed is by placing over the leaf of healthy seedlings of abacá, mosaic leaf without detaching either from the mother plant and then by means of very fine insect pin pricking the infected leaf through the healthy leaf. The inoculated plants failed to take in the mosaic disease.

6. *Inoculation on the stem.*—The methods and technique employed in this work are modifications of what Sien(5) used successfully in his "new mechanical method for artificially transmitting sugar-cane mosaic."

(*a*) White No. 0 Asta insect pins (instead of No. 2) were used for inoculating healthy abacá plants. A slip of a mosaic leaf of about an inch wide and three inches long was inserted between the first and second leaf sheaths and held tightly with the thumb and forefinger of the left hand. Then with the pin in the right hand the leaf sheaths were pierced rapidly in and out at different parts passing through the mosaic leaf into the healthy tissue of the pseudostem. This method was repeated three or four times, each time a fresh mosaic leaf between the

different leaf sheaths was always used. In a series of trials, the results were all negative.

(*b*) Following the methods used by Stevenson(6) in his attempt to transmit the sugar-cane mosaic artificially, the writer inserted small bits of diseased tissues into the various parts of the pseudostem of healthy abacá plants, but in all the attempts made negative results were also obtained.

7. *Inoculation of the root.*—Both young and old abacá seedlings were dug up from the seed box and the roots washed thoroughly in running water. By means of fine sterilized insect pins, the young unfolded mosaic leaf was pricked through the healthy tissues of the old and young roots of the abacá seedlings. Then the inoculated plants were planted in pots containing sterilized garden soil. The results obtained were all negative.

8. *By means of hypodermic syringe.*—Injection by means of hypodermic syringe was also resorted to in an attempt to transmit the abacá mosaic to healthy plants. After extracting the juice from the old and young unfolded leaves of mosaic-infected plant and straining through a certain thickness of clean cheesecloth, the undiluted juice was taken up with a syringe and injected immediately into the pseudostem and leaf-axil of the healthy abacá plants. Eight potted plants were injected with the virus and four plants were injected with sterile water as control. Both the inoculated and controlled plants remained healthy after six months.

9. *Planting healthy abacá seedlings side by side with mosaic plants in the greenhouse.*—In May 1935, five abacá rootstocks taken from mosaic stools in Davao were planted in a plot inside the greenhouse.[2] All plants developed mosaic disease. Later, they were found heavily infested with aphids, *Pentalonia nigronervosa* Coq. (Plate 1).

(*a*) On September 27, 1935, five healthy plants (two Maguindanao and three Tañgoñgon) were planted side by side with the mosaic plants in the greenhouse (Plate 3). On October 29, 1935, the first symptom of mosaic was noted on one of the plants of the Tañgoñgon variety. On October 30, 1935, the other plant of the Maguindanao variety manifested the symptoms of the mosaic disease. On November 3, 1935, one plant of the Tañgoñgon variety was infected with mosaic and on November 13, 1935, the other Tañgoñgon variety showed the symptoms of mosaic disease. Only one plant (Maguindanao variety) failed to

[2] This greenhouse has a glass roof and metallic-cloth sides.

show the symptoms of mosaic. Examination of those infected plants revealed the presence of numerous aphids, *P. nigronervosa* Coq. No other insects were found.

(*b*) In line with the above experiment, one potted healthy abacá seedling of the Maguindanao variety was placed in close proximity with the mosaic-infected plants in the same plot in the greenhouse. (Plate 3). On October 30, 1935, this particular plant showed decided symptoms of mosaic infection (Plate 2, fig. 3.) The same aphids, *P. nigronervosa* Coq. were also found feeding on the plant and no other insects were found associated with it.

According to the results of the present experiments, *P. nigronervosa* seems to have some relation with the transmission of the abacá mosaic. However, the definite relationship of this insect with the disease may be established later by detailed experiments conducted under properly controlled conditions. In view of the presence of other sucking insects that have been frequently observed in considerable number feeding and breeding on both mosaic and healthy abacá plants in the field, it seems necessary that the possibility of these insects as vectors of the abacá mosaic should be investigated. The most important of these insects are the lace bugs, *Stephanitis* sp.[3] and a certain species of leaf hoppers. Experiments along this line are now underway.

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[3] The lace bug was identified by Mr. F. Q. Otanes, Chief, Entomology Section on November 26, 1938.

ILLUSTRATIONS

Plate 1

A portion of an abacá leaf infected with mosaic. Note the presence of brown aphids, *Pentalonia nigronervosa* Coq. (Natural size) feeding on the tender midrib. Photographed by the Bureau of Science, Manila.

Plate 2

Fig. 1. Potted abacá seedlings (Maguindanao variety) placed inside the greenhouse far from a plot where mosaic diseased abacá plants were planted. This plant is the control of Fig. 3. Note that at the end of the experiment this particular plant remains healthy.

2. This abacá plant (Maguindanao variety) was planted on September 27, 1935 in a plot in the greenhouse side by side with mosaic abacá as shown in Plate 3 marked X. On October 29, 1935, the symptoms of mosaic disease were first noted. The plant was dug up, planted in a pot, and photographed.

3. Potted abacá seedlings (Maguindanao variety). On September 27, 1935, this potted plant was placed side by side with mosaic diseased abacá in a plot inside the greenhouse. On October 30, 1935, the symptoms of mosaic disease appeared. Note also that there are plenty of aphids.

Plate 3

A plot in the greenhouse planted to five abacá rootstocks taken from mosaic-infected stools in Davao. All plants developed mosaic disease. The same plant marked X is shown in Plate 2, Fig. 2, after it has been infected with mosaic and planted in a pot.

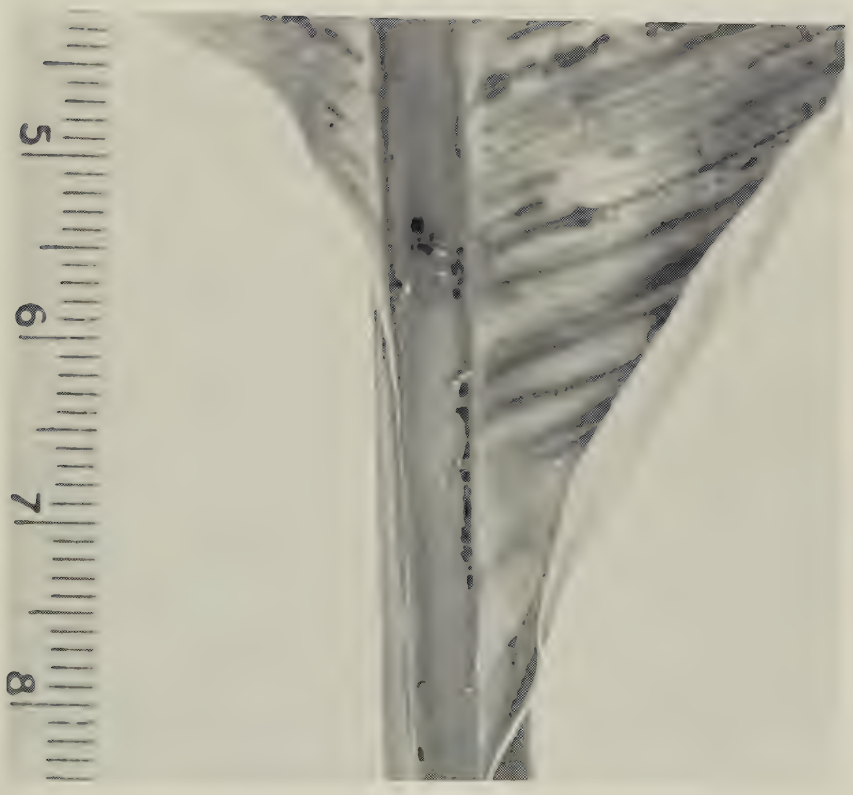

PLATE 1.

PLATE 2.

PLATE 3.

AVOCADO CULTURE

(Farmers' Circular 1)

By F. G. GALANG

Of the Horticulture Section Bureau of Plant Industry

FOUR PLATES

In its native home, tropical and semitropical North and South America, the avocado (*Persia americana* Mil. and *P. drymifolia* Ch. and Sc.) is an important food of the inhabitants. In the Philippines, however, it is still considered a luxury fruit since the present price is not within the reach of many. Of the many species and varieties of fruit trees introduced into the Philippines, none has gained so wide a reputation within a short time as the avocado. Although it is said to have been brought into the Philippines from Mexico in 1890, yet it was not successfully grown here until 1903 from planting materials received from Hawaii, Costa Rica, and the United States. The Bureau of Agriculture (now the Bureau of Plant Industry) began the distribution of avocado in the Philippines in 1913, and with the coöperation of the College of Agriculture of the University of the Philippines, it is able to produce many avocado trees bearing fruits in many provinces. Approximately 22,000 trees are now found growing in the Philippines, 4,500 of which are already bearing fruits.

VARIETIES

Avocado trees vary in habit of growth; some are tall with short lateral branches while others have spreading branches. The leaves are usually medium thick and leathery, and they vary in shape and size. The flowers are borne in compact panicles generally at the end of the twigs. The fruits are variable in shape, size, and color. The surface color of the fruit, when ripe, varies from light green to dark green, purple, brown, red, crimson, or maroon. The rind may be thin and delicate to thick and leathery and enclosing a large seed. The pulp is very nutritious, rich in fat, appetizing, with nutty flavor, and of a buttery consistency. There are three avocado races, namely, the West Indian, the Guatemalan, and the Mexican types. Each

of these types requires a different elevation for its development and possess different characteristics, as follows:

West Indian.—The fruit of this type has a poor shipping quality, loose-fitting, and with rather large seed. According to Stahl they contain from 4 to 7 per cent fat. The skin is medium thick and is always smooth and leathery. The seed coats are usually separated, and the cotyledons are rough on the surface. The fruit stems are short. The Philippine grown varieties under this type as the Pollock, Family, Cardinal, Wilson, Waldin, Wester, and Baldwin.

Guatemalan.—This type has a thick woody rind, producing dull, large, and rough fruits. The seed is small and invariably tight-fitting; the fruits are of good shipping quality, the meat of which is drier than that of the West Indian. The surface of the cotyledons is smooth. It contains more fat (from 10 to 13 per cent) but less carbohydrates. The fruit usually is borne on long fruit stem. The young leaves are frequently reddish or bronze in color instead of green. The Dickinson, Lyon, Tertoh, Taft, and Tumin are the varieties of this type already cultivated in the Philippines.

Mexican (*Persea drymifolia*).—The foliage is anise-scented, small, and sharp at the apex. The fruit is small with thin, smooth rind which generally adheres to the pulp and is of purplish black in color. It contains a higher percentage of fat (from 12 to 15 per cent). The seed is large with thin coats which are either separated or adhering to the cotyledons. The surface of the cotyledons is smooth. The varieties under this type that are already grown in the Philippines as Ganter and Puebla. Seeds of the Gottfried and Northrop were successfully introduced in 1924.

In planting avocado, one of the most perflexing problems is the choice of the right varieties, and this is due to a considerable variation in the productiveness of avocado trees. Some trees profitably bear fruits every year; others, only in alternate years; others do not bear any fruit at all. Many varieties fail to bear fruits satisfactorily owing to lack of pollination brought about by the failure of the flowers to open at the proper time or to the incompatibility of the pollen itself. Generally, fruit bearing in avocado will be more successful if compatible varieties are interplanted and if their flowers open at such time as will permit cross-pollination, or if self-compatible varieties are planted, the opening periods of flowers overlap. However, the varieties to be interplanted should have approximately the same flowering

time—early varieties should not be interplanted with late varieties and vice-versa. The midseason varieties can be interplanted with either the early or late varieties.

Of the hundreds of varieties now planted in the United States, not a single one has so far been selected that gives all the desired qualities. Each has some defects. And these varieties will have to be replaced eventually by a more desirable variety, or strain. In the Philippines, numerous seedlings and named varieties have already been imported and planted. Of those that have so far fruited, some are good, while others produce small fruits of poor quality. Moreover, many had failed to maintain themselves under local conditions. Altogether not less than one-hundred varieties and strains of avocado have already been introduced, out of which about forty varieties are surviving and seventeen are bearing fruits. However, according to the list of avocado varieties given in the 1929–1930 Annual Report of the California Avocado Association, there are 342 varieties, classified as follows: 62 Mexican, 78 West Indian, 152 Guatemalan, and 50 unclassified. In addition a score or more varieties and strains are fast developing in the United States and elsewhere. Therefore, aside from the varieties already found growing in the Philippines there are many more varieties and strains which merit further planting and introduction. Nevertheless, until new varieties, or strains, have proven to be superior and especially adapted to local conditions, the Philippine grown avocado varieties, which have fruited for several years, should be given preference in starting an avocado orchard. Of the many varieties that have been introduced and distributed, only a few have so far gained popularity. The Cardinal, Pollock, Lyon, Wester, Tertoh, Family, Cummins, Commodore, Cyrus, Quality, Douglas, Vega, and Miami have fruited successfully in Lamao, Bataan, and elsewhere in the Islands. But due to the limited extent of their trial, their selection should not be considered final. The Cardinal has predominated, however, probably because of its productive habit under certain soil and climatic conditions.

When selecting the varieties to be planted, one should be guided by the following points: The trees should be hardy, productive, regularly bearing, disease-and pest-resistant, early-or late-bearing; the fruit should be of good flavor, quality, and size; and the seed should be comparatively small. It should be borne in mind that the fat content does not indicate a good quality, for in the United States the most prized varieties are poor in this respect.

REQUIREMENTS

The avocado is distinctly tropical and subtropical in its requirements. There are now avocado trees growing in widely separated localities in the Philippines, and the behavior of these trees clearly indicates that the plant is at home in this country. In localities where the dry season is not too long, they thrive with very little attention. However, when the dry season extends to four or five months, they require some irrigation unless the soil moisture is within the reach of the roots during the driest part of the year.

The tree is not exacting in its soil requirements so long as good drainage is afforded. It is very intolerant of standing water, and cannot endure it for any length of time. Deeply and well-drained soil, which is rich in organic matter, is the best for avocado, but well-drained heavy soil of average fertility will also grow good avocado especially in moist regions. Any soil where citrus trees thrive will produce good avocado trees.

Like most other fruit trees, the avocado does not thrive well in places exposed to strong winds. Its leaves cannot quite resist excessively hot, dry winds. Besides, winds increase the evaporation of water which in turn may cause a heavy dropping off of immature fruits. Also the fruits are liable to suffer injury through rubbing against the branches or against each other, and the danger of the breakage of limbs, especially those heavily loaded with fruits, is increased. However, this is not a limiting factor in avocado culture, because it can be remedied by planting windbreaks in places where there is no natural protection from the winds. Windbreaks reduce the air movement and so diminish evaporation. Windbreaks should be planted around the orchard; if the plantation is large, windbreaks should be planted in every hectare lot.

The West Indian varieties are very tender, and are best adapted to low and medium elevations up to 900 meters above sea level. The Guatemalan varieties are rather intermediate, and have wider range of adaptability. They can be grown from sea level up to an elevation of 2,500 meters, but an elevation of not more than 700 meters is the best. The Mexican varieties are the hardiest with respect to cold weather, and have a wide distribution. They thrive best from 600 meters upward.

PROPAGATION

The avocado is propagated by seeds, by budding, grafting, inarching, or marcotting, but preferably by budding and graft-

ing. Inarching and marcotting are too laborious and expensive. Grafting sometimes gives a better result than budding. The grafted plants are oftentimes more vigorous than the budded ones. On the other hand, trees grown from seeds usually do not come true to type. The chances of obtaining a fruit of better quality than that produced by the parent tree are very slim. It is the experience of avocado growers that seeds are unreliable means of reproducing a variety. However, if seeds have to be depended upon for the propagation of avocado, the seed of some avocado varieties may be carefully halved so as to produce two plants from each seed. The resulting plants, however, should be given a reasonable dose of fertilizer in order to produce good growth. Generally the whole seed germinates earlier, and the resulting seedling is more stocky and has more number of leaves than the halved seed.

The first step in the production of budded or grafted trees is the raising of the stock plants. In the United States the varieties of the Mexican type are commonly used as stock plants because of their greater hardiness against frost than the large-seeded and hard-shelled varieties in spite of the greater amount of plant food in the seed of the latter. But this type possesses a wide range of variability, and caution should, therefore, be taken in using it as a stock plant in the Philippines. On the other hand, the West Indian seedlings, being generally more vigorous than the other types, may prove good stock plants at lower altitudes in the Philippines, although they were proven less successful as scion for the Mexican stock. The Guatemalan type will succeed both the West Indian and the Mexican stocks. This type is vigorous and thrifty, but somewhat tender although less so than the West Indian. Fuerte, a hybrid between Guatemalan and Mexican types is much used as stock plant in the United States nowadays.

As the seed of the avocado loses its vitality quickly, it should be planted while it is still fresh. And if the seeds cannot be planted at once, they should be stored in properly moistened sand, sawdust, charcoal, or sphagnum moss. The seeds may be planted directly in bamboo pots or in seed beds with the pointed end up. About one-fourth of the seed should be left exposed so that the resulting sprouts can be thinned out, leaving the strongest one. Set the seeds 40 or 50 cm apart in the seed beds. In potting, the soil should contain one-third each of sand, loam, and well-rotted compost. If sown in seed beds, the soil need not be so rich—a sandy loam soil being sufficient. It is sometimes advis-

able to grow the seedlings for budding or grafting in the seed beds although it will require more labor to remove them properly when transplanting them in the field. Seeds should not be allowed to dry out, otherwise they will lose their viability.

Budding or grafting is done in the same way as in citrus or other fruit trees. It can be done any time the stem of the stock plants has attained the size a little larger than a lead pencil provided it is not raining and that the seedlings are in condition, that is, the sap is flowing freely. The scion should be selected from the best tree of the desired variety, should be well matured, preferably from twigs which are just ready to send out a new growth, and should contain plump and well-developed buds.

Avocado stem is very brittle so that in forcing the bud to grow, a notch should be made of a few inches above, the bud instead of cutting the stem half-way into the wood of the stock for lopping as in the case of other fruit trees. In lopping never bend the stock as in other fruit trees in order to avoid a premature breaking. When the scion is already well advanced, the top of the stock bay be cut off entirely about 10 centimeters from the bud. After the bud has grown to a length of about 25 cm., the stock should be cut off clean just above the union of the stock and the scion, and the cut surface should immediately be painted with white lead or other suitable materials. This will protect the wood from decay.

PLANTING

When the plants are about 50 cm. high or more, they can be transplanted in the field at the beginning of the rainy season, at a distance of about 8 to 10 meters apart in holes large enough to accommodate the plants. Set the plants as deep as they grow in the nursery, and use good surface soil for refilling the holes. The soil should be packed firmly around the plant. It is well to pour in water while firming the soil. If water is available, planting may, of course, be done late in the rainy season, and even during the dry season. In transplanting, great care should be taken so as not to injure the root system which is very delicate, and the roots should never be exposed to dry or else the plants will die. To avoid the least injury to the roots, the plant should be dug from the nursery with a ball of earth. In planting balled trees, it is necessary to remove the sack or wrapping materials from around the ball of earth as the sack will decay in due time. However, to facilitate the rotting and the

penetration of water, two or three cuts should be made at the sides with a sharp knife. Split and remove the pot in transplanting the potted plant. Cut one-half of the leaves or young twigs of the plant previous to transplanting. The newly transplanted plants should be watered and mulched from time to time as may be necessary. In watering, a basin should be made around the tree to hold the water. Shedding the newly transplanted plant is necessary if planting is made during the dry season. Care should be taken that varieties are planted together which will provide pollen for each other at the time when each is ready for pollination.

ORCHARD MANAGEMENT

A modern fruit tree orchard should be well cultivated, irrigated, fertilized, cover-cropped, pruned, and mulched from time to time. The cultivation of young avocado orchard is done in the same way as in citrus, that is, deep plowing is advisable at the beginning; but when the trees are already big, deep cultivation should be avoided as much as possible, otherwise there is danger of destroying part of the root system and exposing the soil. At this stage the tree can be kept clean by occasional hoeing of the ground near its trunk. Mulching the trees and planting cover crops between the spaces are beneficial for the upkeep of the trees, since both prevent soil erosion and replenish the nitrogen and organic matter of the soil. Legumes have the power of gathering free nitrogen from the air and storing it in their nodules, and are, therefore, more valuable as cover crops than non-leguminous plants.

In order to get the most profit from the trees, it is always a good practice to maintain the fertility of the soil. To accomplish this, fertilizers should be applied regularly to bearing trees. There is a wide diversity of soil in the Philippines so that to give advice regarding the kind and amount of fertilizer without knowing the condition of the soil is almost futile. However, the kind of fertilizer needed by avocado is probably not very different from that needed by other fruit trees although the amount may differ. And in the absence of experimental data no definite and specific information can be given. The condition of the tree and of the soil should be the determining factor as to the kind and quantity of fertilizer to be used.

A young tree requires very little, if any, commercial fertilizer until it begins to bear fruit heavily. Animal and poultry manures and nitrogenous commercial fertilizers are, however, beneficial

to young avocado trees. A complete fertilizer which is low in nitrogen and high potash is good for fruit-bearing trees. In the United States a mixture containing 5 per cent nitrogen, 7 per cent phosphoric acid and 2 per cent potash, the nitrogen being derived from organic materials, has given good results on young trees when applied at the rate of one pound per tree, three or four weeks after planting, and 8 to 10 pounds on five-year old trees. The percentage of potash is increased while the trees come into bearing—5-8-3 or 6-6-3 in spring; 4-8-10 in the fall, and 4-7-5 or 5-5-5 in summer.

As a general rule, avocado requires little or no pruning at all after the tree is properly established. However, inasmuch as the avocado plant is naturally weak and brittle, the pruning of forking branches and shortening of young and spindling twigs may be done to strengthen the stock and the framework of the growing tree. This is to be done at their dormant stage. The mere pinching of undesirable shoots may induce the growth of other buds where an extension is needed in order to make the trees more or less symmetrical in growth. Tall growing trees should be pinched back. Again, some thinning of the branches should be done from time to time so as to permit sunlight into the inside foliage. Of course, any heavy pruning should be avoided, as this will greatly accelerate the vegetative growth and delay the fruiting period. Only dead and undesirable branches should be removed after the fruits have been harvested. All wounds should be painted with white lead or other suitable materials to avoid rotting.

In places where there is a uniform distribution of rainfall, the avocado need not be watered at all, but in places where there is a prolonged dry period, watering is necessary unless the ground water is high or is within the reach of the roots. The water may be distributed in the way which is most convenient, economical, and effective. The furrow system of irrigation should be practised on big plantations whenever it is practicable for the sake of economy, and the bucket system may be used for watering the individual trees around the house. Where there is lack of water in the soil, the trees may shed much of their foliage, flowers, or fruits.

It is often advisable to top-work undesirable trees in the orchard to a good variety. This can be done by cutting the tops back including the big branches. Of the numerous sprouts which appear, only a few good ones should be left for budding or grafting with selected scions. The cut surfaces and the trunk

should be painted and whitewashed in order to protect them from decay and sunburn.

PESTS AND DISEASES

There are comparatively few insect pests and diseases which at present affect the avocado in the Philippines. Among the insects, the borers and the scale insects, including mealy bugs, are found destructive to our avocado trees. Other pests are the thrips, caterpillars, and white ants.

The borers are found to attack the trunk, pith, and twigs. They work their way downward destroying all growth thereby, and may eventually kill the tree. Lime wash may lessen the infestation.

The caterpillars attack the leaves and flowers. They can be controlled by spraying either with lead or calcium arsenate.

The thrips attack the flowers, but they can be prevented by dusting with pyrethrum, derris powder, or tobacco dust.

The scale insects suck the sap of twigs, leaves, and fruits. Heavy infestations weaken the tree, and sometimes cause premature falling of fruits. Oil emulsions and soap suds are usually effective in controlling the scales.

The important diseases of avocado are die-back and anthracnose. The anthracnose is a disease of the leaves, bark, and fruit. The affected portion turns black with sunken spots, usually circular in form. It can be controlled by spraying with Bordeaux mixture. The infected parts should be cut and burned.

The die-back is a disease of the twigs. The infected parts become dry. It can be prevented by spraying the trees with lime sulphur or Bordeaux mixture. These sprays should be applied periodically once every two weeks at least as the new flushes appear until they mature.

Other diseases of minor importance which may also be controlled are the scab and the leaf spots.

HARVESTING AND YIELDS

The avocado season in the Philippines is from January to March and from June to September, depending upon the climate of the locality. In humid districts the season is rather early. There are, therefore, only two short periods in the year during which avocado fruit is not obtainable in the market—from April to May and from October to December. However, by planting varieties which fruit at different times of the year, it is possible to produce avocado fruits all the year round. In the United

States the Fuerte variety is said to be fruiting from November to May; Verde from March to May; Puebla from November to December; and Taft from May to November.

Avocado trees grown from seedlings begin to bear fruits when about four to eigth years old, six being the average. On the other hand, vegetatively grown trees sometimes begin to bear fruit the first year in the nursery. At this age, however, and probably up to three years, they should not be allowed to fruit at the expense of the future growth and vigor. The annual yield of a full-bearing tree ranges from a few to 500 fruits—sometimes from 800 to 1,200 fruits. An average of 500 fruits a year per tree is considered a fair yield. Generally the yield varies from one season to the next, partly depending upon the size of the previous crop, rainfall, winds, and the conditions of the tree at the flowering season.

The avocado fruits are very perishable and should be handled with care. In harvesting, the fruits should be carefully clipped off, leaving a short stem on them for handling purposes. A fruit picker provided with a knife similar to that one used in picking the mango fruits should be used in harvesting the fruits of tall growing trees. Furthermore, the avocado should be harvested when fully matured, and not allowed to ripen on the tree. The maturity of the fruit is indicated by its color. For example, the appearance of reddish streaks in the case of purple fruiting varieties and the change of color from green to a lighter green in the case of green varieties are indications of maturity. In the thin-skinned forms the ripeness of the fruit can be determined by external pressure, but in the very thick-skinned varieties this cannot be done. The ripeness of the fruit of the latter varieties can be determined by the stems when it is easily pulled out of the fruit, and when a toothpick can be easily pushed through the stem it indicates that the fruit is ripe enough for eating. If the fruit is picked before reaching maturity, its flavor is poor, while if left too long on the tree, the keeping quality is impaired. The fruits should be placed in a basket or box lined with packing materials, such as dried straw, banana leaves, etc., when intended for short distance shipment; when the fruits are to be shipped long distances they should be wrapped individually with soft tissue paper.

USES

The avocado fruit is rich in fat and protein but low in sugar content. Its oil is similar to olive oil and can be used for the

same purposes. It has been known in countries where avocado has been long grown that its fruit is a wholesome and highly digestible food. Wolfe and others said that an ounce of avocado contains about 73 calories, which is nearly three times that of banana, one and a half times that of beefsteak and other meats, and three times that of several kinds of fish. And because of this and its low carbohydrate content it is a good food for diabetic people. Its iron content is about three times that found in other common fruits and, therefore, it is a good food for anemic people.

In the Philippines the fruit is eaten with sugar and milk, or in frozen form, or as ice-cream ingredient. Few people eat the meat offhand. In the United States it is extensively used as a salad fruit because of its delicate, nutlike flavor, and its smooth, buttery consistency. The avocado should not be considered merely as a salad fruit but as a substantial food which may be used in a great many combinations. For it is also eaten offhand, with the addition of lime or lemon juice, or salt, or sugar only. Mashed and seasoned, the meat is used as sandwich filling, or is spread on salted crackers. Often it is also added to soup just before serving. A number of recipes on how to eat avocado fruit has been published from time to time.

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ILLUSTRATIONS

PLATE 1

An avocado tree top-worked to 15 varieties at the Lamao Horticultural Station, Limay, Bataan. The scions fruited at the age of 1 year and 7 months.

PLATE 2

Budded Cardinal avocado at the Lamao Horticultural Station, Limay, Bataan.

PLATE 3

Budded Pollock avocado at the Tanauan Citrus Experiment Station, Tanauan, Batangas.

PLATE 4

Avocado seedlings grown from whole and halved seeds.

PLATE 1.

PLATE 2.

PLATE 3.

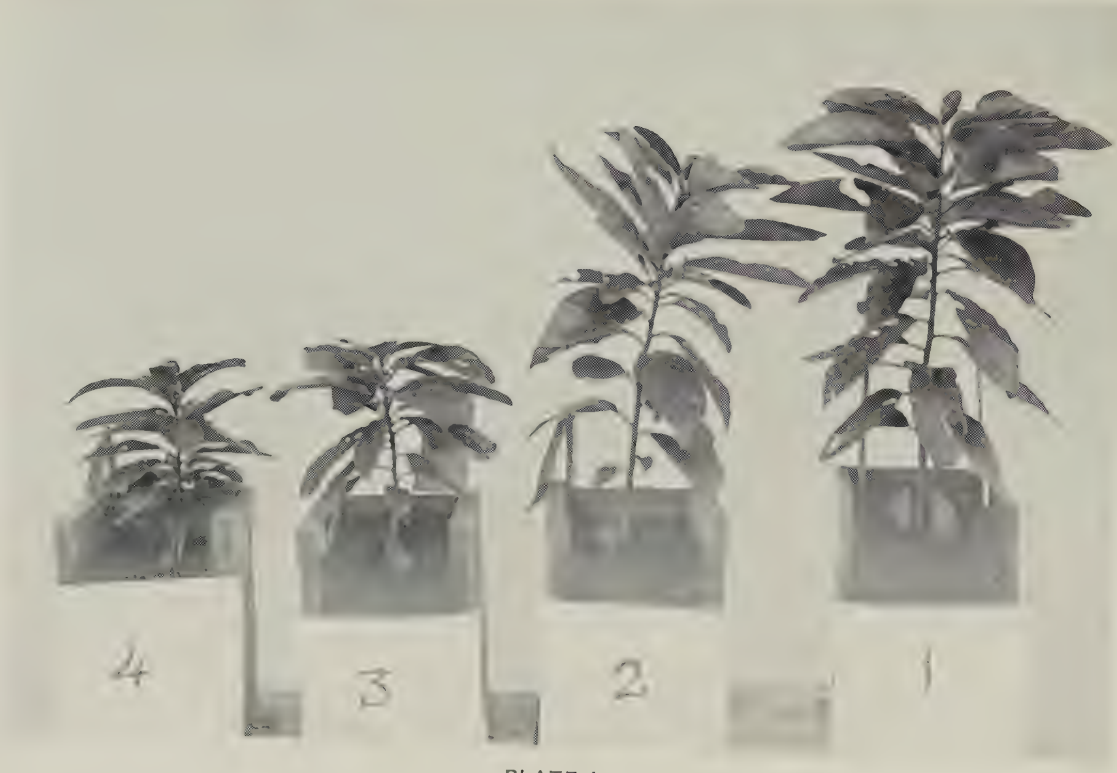

PLATE 4.

THE THREE DESTRUCTIVE DISEASES OF ABACÁ IN DAVAO (BUNCHY-TOP, MOSAIC, AND THE VASCULAR DISEASE) AND THEIR CONTROL

(Farmers' Circular No. 35)

By Melanio R. Calinisan

Assistant Plant Pathologist, Bureau of Plant Industry

THREE PLATES

At present, there are at least three very destructive diseases of abacá, or Manila hemp, which are threatening the abacá industry in the province of Davao; namely, (1) the vascular disease of abacá, or abacá wilt (Plate 1), (2) the bunchy-top (Plate 2), and (3) the mosaic (Plate 3).

The bunchy-top, it may be recalled, is responsible for the total destruction of the abacá industry in Cavite, Batangas, and Laguna and partly in Mindoro. In Cavite alone, 12,843 hectares of abacá plantation were practically wiped out by the bunchy-top disease within a period of 10 years. The bunchy-top was discovered in Davao since 1931; the mosaic, in 1933; and the vascular disease, in the later part of 1936. Continuous eradication measures against the bunchy-top conducted by this Bureau since 1931 up to date saved the industry from complete ruin.

Inasmuch as the aforesaid diseases have the tendency to spread far and wide, it is imperative that immediate action be taken in plantations where these diseases are present.

VASCULAR DISEASE

Symptoms.—The symptom of this particular abacá disease is manifested by the presence of dark-brown morbid portion at the base of the plant close to the surface of the ground (see Plate 1). The blackening or rotting presumably works inward and upward, eventually affecting the leaves of the plant. The older leaves turn yellow and the growth of the youngest ensuing leaf is retarded. Occasional cracking of the leaf sheath at the base may be observed. A longitudinal section and cross-sections of the diseased plants reveal the presence of reddish pink to crimson-like discoloration of the fibrovascular tissues of the corns and

stalks which at times may extend up to the petioles of the leaves. To all appearances, this particular disease is very similar to, if not identical with, the banana wilt, or Panama disease. The abacá plants are attacked, regardless of age.

Cause.—Nothing definite is as yet known about the real cause of the disease. However, in wilted or dead plants, a fungus very similar to that causing banana wilt and known as *Fusarium cubense* and a weevil, *Odoiporus paganus* Uichanco, are associated. Oftentimes, pure culture of bacteria were isolated from the corm, pseudostem, and from the very tip of the discolored tissues of the petioles of the leaf. Further investigations are in progress to determine the definite cause.

BUNCHY-TOP

Symptoms.—The term "bunchy top," although self-explanatory is meant more than a mere bunching of the aërial portion of the abacá plant (see Plate 2). The growth is arrested. The petioles arise apparently from the same plane on the stalk. The leaves assume a more or less rossette arrangement. The affected plants are stunted, or dwarfed. The leaves gradually become shorter and narrower until finally they become almost devoid of the leaf blade. The leaves tear along the margin and usually curl toward the inside. The crowding of the leaves is very conspicuous in the advanced stage of the disease.

Cause.—It is definitely known that the bunchy-top disease of abacá is caused by a virus which is present in the sap of a diseased plant. This virus is so minute that it cannot be seen under the most powerful microscope. However, one thing is certain: the virus is carried and transmitted from diseased to healthy plants by the dark-brown aphid, or plant louse, *Pentalonia nigronervosa.* Before these aphids can transmit the disease to healthy plants, they have to feed first on the diseased abacá by sucking the sap which contains the virus in the same manner as a mosquito (Anopheles) carries and transmits malaria from a malaria patient to healthy persons. No other means of transmission is known.

MOSAIC

Symptoms.—The most typical characteristic symptom of abacá mosaic is the mottling of the leaves (Plate 3). The mottled areas consist of dark-green and yellowish pale-green patches which are plainly visible on both surfaces of the infected leaves, petioles, and sometimes, although less frequently, on the pseudostem.

Cause.—In the case of abacá mosaic, it is believed that this disease is also caused by a virus which may be transmitted from diseased to healthy plants by the same sucking insect, the aphid, or plant louse. The mosaic, like the bunchy top, is also carried over to the new plantation by planting either diseased suckers and rootstocks or those taken from diseased stools.

SUGGESTIONS FOR CONTROL

The old adage, *"an ounce of prevention is worth a pound of cure,"* is decidedly applicable to these three very dangerous diseases of abacá.

Where the bunchy-top, the mosaic, and the vascular diseases are not yet present, it is important to practice strict exclusionary measures. In this connection it is necessary to prohibit the movement of propagative materials (suckers and rootstocks) of abacá and banana or any other plant belonging to the genus *Musa* from localities infested with these dangerous diseases to regions where the same trouble is not yet known to occur. The risk lies in the fact that such propagative materials may harbor the disease or may carry with them the virus-bearing aphids which are the principal carriers of the bunchy-top and presumably of the mosaic. It should be borne in mind that these insects or diseased plant parts, are liable to be carried from disease-infected districts to a disease-free locality through certain means, like soil, leaves, and leaf sheaths of abacá and banana which are often used for wrapping propagative plant materials or any product for shipment.

If the bunchy-top, the mosaic, and the so-called vascular diseases appear in any abacá-growing district despite rigid quarantine measures, there is no other alternative but to take immediate steps to eradicate them. The method is quite simple, and what has been proved with success to control the bunchy-top may also be employed effectively to control the mosaic and the vascular diseases.

If the disease is still localized, the whole plantation should be surveyed row by row to locate all plants infected with any of the three diseases. As soon as a bunchy-top or a mosaic hill is located, pile a big heap of dried abacá leaves and debris on the base and on top of the plants between the petioles of the leaves and burn them. Necessary precaution should be taken to give the aphids no chance to escape and migrate to neighboring healthy plants. After the burning is done, the plants should be dug out including the corm and chopped into small pieces right on

the same spot. They should be burned completely for the second time by using dried abacá leaves or other combustible materials. The first burning is employed to kill the aphids, the second to destroy the sources of infection.

In the absence of more definite information about the nature and real cause of the vascular disease, it is believed, that constant roguing and burning of all diseased plants *in situ* as fast as they appear would check the rapid progress of the disease. The above procedure should be done until the whole plantation is thoroughly surveyed and all diseased plants are removed and properly disposed of. In this way the disease may be controlled entirely.

If, on the other hand, the bunchy-top, the mosaic, and the vascular diseases are already widespread in a more or less epidemic form, it is suggested that all mature stalks free from disease be harvested or stripped, and then the entire plantation should be burned. Dig out the plants as previously described and destroy them completely. Clean the field thoroughly and plant rice, corn, potato, or any other temporary crops, like soybeans and other crops suitable to the place. After a year or two, plant abacá anew, if so desired. Be sure to get suckers or rootstocks from healthy and vigorous plants only from districts absolutely free from any of the three mentioned diseases. Whenever resistant varieties are available, they should be planted in lieu of the highly susceptible ones.

With this practice, coöperation between all the abacá growers is essential in controlling these three dangerous diseases of abacá. Everybody should do his bit for no matter how intelligently and seriously a farmer sets himself down to his task, he is helpless if his neighbors are indifferent. A community spirit will help wipe out these troubles and save the industry.

For further information consult the Bureau of Plant Industry, Manila or local office of the Provincial Agricultural Supervisor and work with them to control the disease.

ILLUSTRATIONS

PLATE 1

Abacá plant, Maguindanao variety, attacked by the vascular disease. Note the rotting or blackening at the base of pseudostem and the wilting of the leaves.

This specimen was collected from Mindanao Reclamation Co., Tongkalan, 1,750 ft. above sea level.

PLATE 2

A typical illustration of young abacá plants infected with the bunchy-top disease. Note the bunchy appearance of the leaf and the stunted growth of the plant.

Photographed by Mr. Kojima of the Ohta Development Co., at Dacudao Plantation, Davao.

PLATE 3

Young abacá suckers infected with mosaic disease. Note the mottled areas consisting of dark-green and yellowish pale-green patches on the leaves, petioles, and pseudostem.

PLATE 1.

PLATE 2.

PLATE 3.

BUREAU OF PLANT INDUSTRY

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2. Lamao Horticultural Station, Limay, Bataan
3. Lipa Coffee-Citrus Station, Lipa, Batangas
4. Tanauan Citrus Station, Tanauan, Batangas
5. Granja Sugar-Cane Station, La Granja, Occidental Negros
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2. Halcon Rubber Substation, Baco, Mindoro
3. Gingoog Lanzon Reservation, Gingoog, Oriental Misamis
4. Mandaue Seed Farm, Mandaue, Cebu

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